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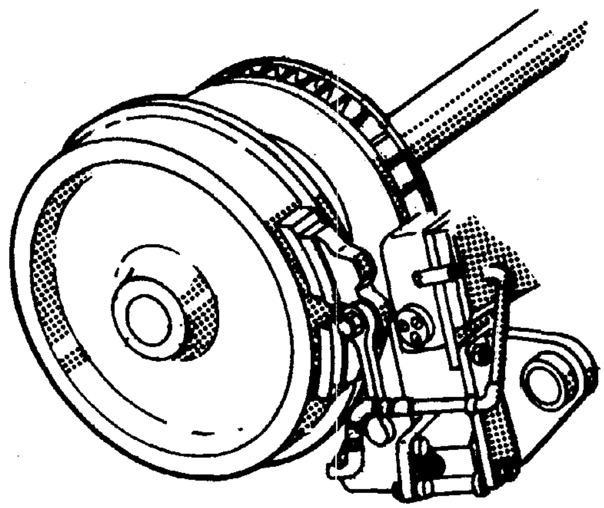
TEST RESULTS REPORT

DUAL DISC/TREAD BRAKING AND REDUCED PRESSURE BRAKING EVALUATION PROGRAMS



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AMTRAK
400 NORTH CAPITOL STREET N.W.
WASHINGTON, D.C. 20001

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16. Abstract

This report is the Test Results Report for the Dual Disc/Tread Brake Test. Data logs and records associated with this test are published separately in the Test Events Report Dual Disc/Tread Braking and Reduced Pressure Braking Evaluation Programs, Report No. FRA/ORD-81/21. The Dual Disc/Tread Braking Test was conducted to investigate the benefits of using dual systems on the Amcoach. The test evaluated candidate systems developed by Knorr-Bremse, New York Air Brake and Westinghouse Air Brake Company. The test showed that as presently configured, the Amcoach may often exceed the available adhesion and tend to experience momentary wheel sliding which causes spalling. The test indicated that the dual brake system may help to improve tread life and extend the capacity without over heating either the wheel tread or the disc. In addition to the single car cutaway test of the dual brake system and a normal Amcoach braking system, a special reduced pressure test was performed on the Amcoach. The results showed that reducing the full-service braking pressure may be an alternative way of reducing the adhesion demand at the lower speed to relieve the wheel sliding problem. This approach extends the stopping distance by only a small amount but does not provide a mechanism for maintaining the wheel/tread surface or increasing the overall system capacity as does the dual brake system.

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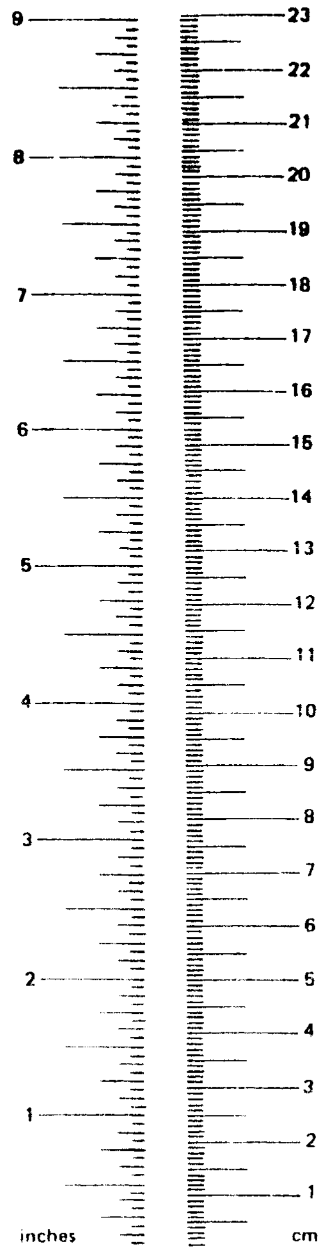
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

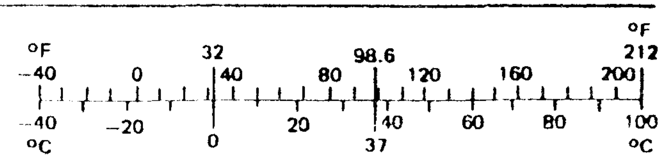
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 cm (exactly). For other exact conversions and more detail tables see NBS Misc. Publ. 286. Units of Weight and Measures. Price $2.25 SD Catalog No. C13 10 286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

The purpose of the Dual Disc/Tread Braking Test was to investigate the potential benefits of the dual-brake system, and to evaluate candidate dual-brake hardware for use on Amcoaches and other cars to be used in 120-mph service on the Northeast Corridor (NEC). This test was designed to evaluate the candidate dual-brake hardware prior to the introduction of this hardware into NEC operations for extended in-service evaluation.

At operating speeds above 100 mph, passenger cars equipped with tread brakes (only) often develop serious wheel problems during braking (due to excessive heat build-up). Disc (only) systems do not incur wheel damage because of overheating, since almost all of the heat developed during braking is dissipated by the disc. However, the incidence of wheel-tread, surface-defects such as spalling and shelling increases when there are no tread brakes or scrubbers on the wheels. Available adhesion increases at low speeds, but the adhesion demands of Amcoaches increase sharply at lower speeds. Therefore, the demand is very close to dry-rail conditions. The reduction in demand (displayed at the lower speeds by the dual-brake systems) means that there would be fewer occasions when the wheels tend to slide. The slide control system prevents serious slides but the wheel has to slide a short distance before the system can detect that the wheel is about to slide. Some damage is done every time the wheel begins to slide. This type of small damage produces spalling on the tread surface. Therefore, preventing small slides would save many wheel-tread defects.

The tests show that the Amcoaches have a relatively high deceleration rate which means that the adhesion demands may often exceed the available wheel/rail adhesion for wet rail or other marginal conditions. Amcoaches are a typical example of a car equipped with disc brakes (only). At present speeds (below

100 mph), the discs are capable of dissipating the heat, but the wheel treads must be turned frequently to eliminate tread-surface defects. When the cars are operated at higher speeds, the disc temperatures will increase. Therefore, the incidence of disc-thermal-cracking and disc-pad overheating can be expected to increase and wheel damage become much more severe.

A dual disc/tread braking system is under consideration as a possible solution to the overall braking problem. The dual brake system will increase the capacity without overheating either the wheels or discs. The tread temperatures must be limited to avoid thermal cracking of the wheels, but the wheels can dissipate enough heat to significantly reduce the amount dissipated by the disc. At present discs on the Amfleet do not normally overheat. Adding the tread brake will increase the dissipating capacity so that the disc temperatures do not increase much when the speed is increased from 97 MPH to 120 MPH as planned for the upgraded corridor service. At the same time, the addition of tread brakes should reduce wheel tread damage. The tread-brake shoes clean the surface of the wheel and seed the wheel surface with particles which help to improve wheel/rail adhesion.

The Dual Disc/Tread Brake Test consisted of single-car, stop distance tests of an Amcoach equipped with standard disc-brakes and three other Amcoaches equipped with dual disc/tread brake systems developed by Westinghouse Air Brake, New York Air Brake and Knorr Brake Corp. under a joint FRA/Amtrak sponsored dual brake development project.

In addition to the single-car cutaway tests, the cars equipped with the dual brake system and the standard car were run as a consist on a simulated Northeast Corridor operation of 10,233 miles, and a special reduced-pressure test was performed on the standard Amcoach (No. 21018) equipped with disc brakes only.

The results of the stop distance tests showed that all three dual brake systems were capable of matching the performance of the disc brake (only) system presently used on Amfleet cars. The stop distance tests on the standard Amcoach also showed that the braking rate on a standard Amfleet car is much higher than the required rate in the car specification at speeds below 40 mph.

The test showed dramatically the benefits of using tread brakes. When the dual-braked cars were operated at braking rates similar to those of a standard Amcoach, they performed as expected and showed the unexpected benefit of operating at lower braking rates below 40 mph. Wheel defects incurred by some of the cars while being moved to the Transportation Test Center were cleaned-up by the dual disc/tread brake units, and the wheels on the dual-braked cars were much freer of defects after the test than before.

The discs in the dual-brake systems operated at much lower temperatures than the discs in the disc-only system. The tests showed that the disc temperatures on the standard Amcoach were not excessive for normal braking from speeds as high as 120 mph. However, the temperatures resulting from power braking and repeated high speed stops were relatively high. Under normal full-service braking from 120 mph, the disc temperatures on the dual brake cars (at both 50/50 and 60/40 disc/tread ratios) were approximately 100 degrees less than those measured on the standard Amcoach. When the dual-brake cars were operated at the 50/50 disc/tread ratio, wheel tread temperatures exceeded disc temperatures. Therefore, it appears that the 60/40 disc/tread ratio is better than the 50/50 disc/tread ratio.

Only the Knorr/Bremse equipped car was tested at a higher disc/tread ratio. The results from this test (where the ratio was 70/30) indicated that the disc temperatures were nearly as high as the disc temperatures for the disc only system, and the tread temperatures were not much lower than the temperatures measured in a similar test at the 60/40 disc/tread ratio.

The results of the special test* of a standard Amcoach operated at reduced brake-cylinder pressure showed that the existing disc only brake system can be readjusted to operate at lower braking rates. The additional stopping distance required at full-service brake application (with brake cylinder pressure reduced from 68 to 55 psi) was only 700 feet more than the 5000 feet normally required to stop a car from 120 mph. The signal block on the NEC will be from 9000 to 13000 feet so the car can still stop within one signal block with the reduced brake rate. The reduction in brake cylinder pressure changed the braking-rate performance characteristics so that deceleration was significantly reduced at slow speeds. Since the full-service rate for standard Amfleet cars is relatively high, the reduction in adhesion demand resulting from reducing the full-service braking pressure offers an alternate approach to reducing wheel damage on Amfleet cars.

One of the most expensive operations in modifying the existing Amfleet trucks to accept the dual-brake hardware is that installation of most of the systems requires that the truck be completely disassembled so that the truck frames can be heat treated after the heavy mounting brackets are welded to the

*A complete copy of the Test Events Report - Dual Brake Evaluation Program - Reduced-Pressure Braking Test is included in Appendix E with its own Executive Summary.

truck frame. It is significant to note that the extensive disassembly and heat treatment were not required in the New York Air Brake modification. This system was mounted entirely to the structural tubing which supports the existing disc-only brake system on Amfleet cars. If a system can be developed that can be supported by the existing structures or in some way added to the existing trucks (without complete disassembly and heat treatment), the cost of the dual-brake modification would be much less.

The test results and the hardware demonstration seem to indicate that a tread-brake system can be developed for installation on existing Amfleet cars. This system should have the following characteristics:

- The brakes should be actuated pneumatically.
- The brake cylinders should operate at the same pressure as the existing disc-only system.
- The tread brakes should provide no more than 40 percent of the braking effort and possibly as little as 30 percent.
- The tread-brake system should be designed to be mounted on the structural tubing that supports the existing disc-brake system.
- The combined disc/tread system should have braking rates consistent with the dual-brake test results and braking-rates below 40 mph should not exceed 2.6 mph/second.

It is important that the dual-brake system be designed to be adaptable to existing hardware, and its installation should not require the complete disassembly of existing trucks. However, the new hardware must be rugged enough to survive the harsh environment in which the Pioneer III trucks operate.

1.0 INTRODUCTION

1.1 BACKGROUND

At speeds above 100 mph, passenger cars equipped with tread brakes have a history of developing serious wheel problems during braking (due to excessive heat build-up). Disc-brake systems have been successfully designed to dissipate the heat associated with braking a passenger train from speeds greater than 120 mph. The disc brakes have eliminated the heat-related wheel problems. However, the incidence of wheel-tread-surface defects (such as shelling and spalling) is much greater when tread brakes are not used. There is also a suspected reduction in wheel/rail adhesion due to contamination of the tread surface and lack of the seeding provided by particles from the tread-brake shoes.

The loss of adhesion contributes to wheel/slip and the resultant wheel damage, thus increasing maintenance costs. The collective results of international experience indicate that a dual disc/tread braking system is better for high-speed operations. When a dual disc/tread system is used, the disc brakes can be made to dissipate most of the heat generated in a stop. Therefore, the wheels do not overheat. The tread brakes keep the wheel-tread surfaces clean, and improve wheel/rail adhesion by seeding the wheel-tread surfaces with particles from the brake shoe. The wheel can dissipate enough heat (without overheating) to reduce the heat that the disc brakes would have to dissipate. The discs on existing cars normally operate at acceptable temperatures, but the cars are operating at speeds of less than 100 mph. Increasing the car speed from 95 to 120 mph increases the heat-dissipation demand by 50 percent. In addition to other benefits, the dual disc/tread system will relieve the disc from having to dissipate all the heat and will keep disc temperatures within safe operating limits when the cars are used in high-speed (120-mph and over) service.

1.2 PURPOSE

This test (sponsored jointly by the Federal Railroad Administration and Amtrak) was designed to demonstrate the potential benefits of dual-brake systems and to define the dual-brake system operating parameters required to yield stopping characteristics similar to those of an Amfleet coach. A second objective of the test was to determine the suitability of the dual-brake system for use in Northeast Corridor (NEC) revenue service operation for extended in-service evaluation.

A third purpose (added to this test as a possible interim solution) was to evaluate the results of reducing full-service braking pressure from 68 to 55 psi in relation to stopping distance, wheel slide, reduced wheel damage and adherence to NEC block standards.

1.3 TEST DESCRIPTION

A series of single-car, cutaway, stop distance tests (at specified speeds) were performed on a car (No. 21018) equipped with standard disc brakes. The same series of tests were performed on three dual-braked cars (Nos. 21044, 21063 and 21087). Car No.21044 was equipped with dual brakes designed by Westinghouse Air Brake Company (WABCO), Car No. 21063 with dual brakes designed by New York Air Brake (NYAB), and Car No. 21087 with dual brakes designed by Knorr. The WABCO brakes are shown in Figure 1-1, the NYAB brakes in Figure 1-2 and the Knorr brakes in Figure 1-3. These brake systems are described in more detail in Appendix F of the Test Events Report (ENSCO Report No. DOT-FR-80-21).

1.4 TEST ZONE

The stop-distance tests and the reduced pressure tests were performed on the Railroad Test Track (RTT) at the Transportation Test Center (TTC) in Pueblo, CO between Stations R 14.5 and R 25.5. This zone (approximately 11,000 feet) was chosen

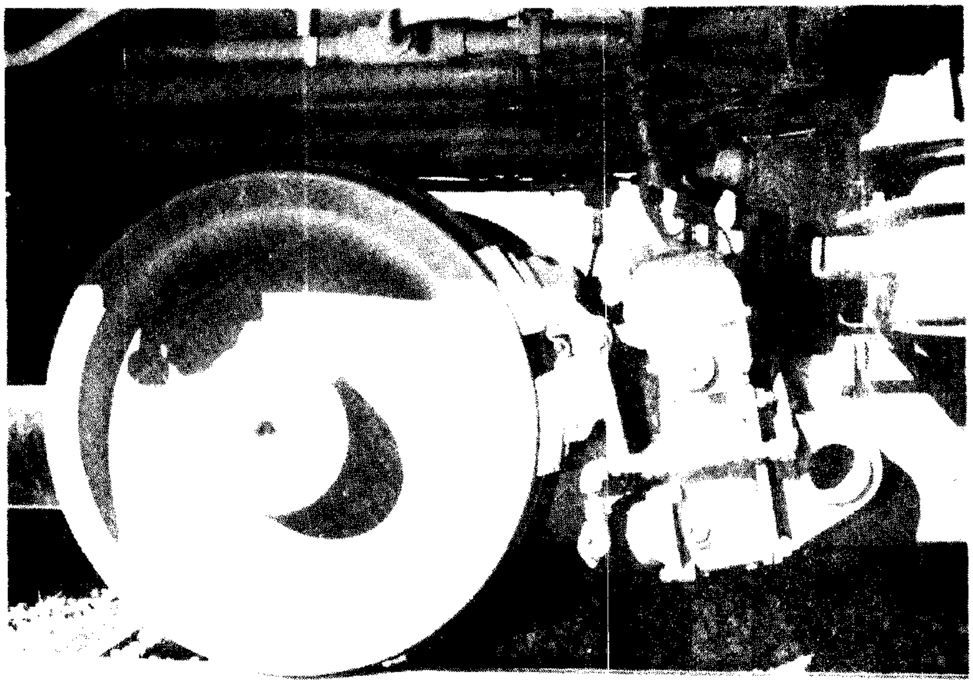

Figure 1-1. WABCO Dual-Brake System

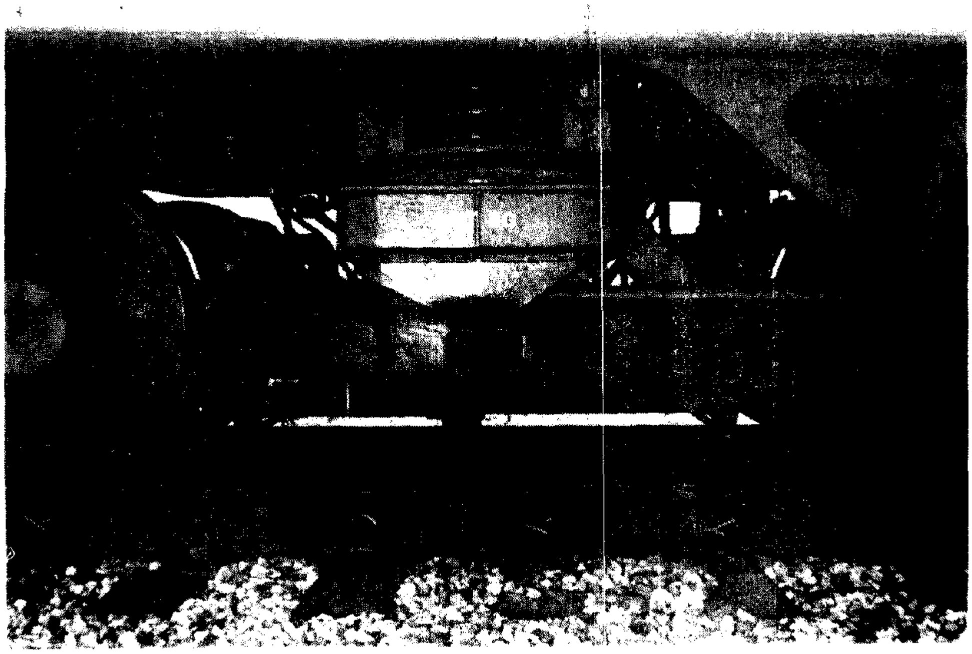

Figure 1-2. NYAB Dual-Brake System

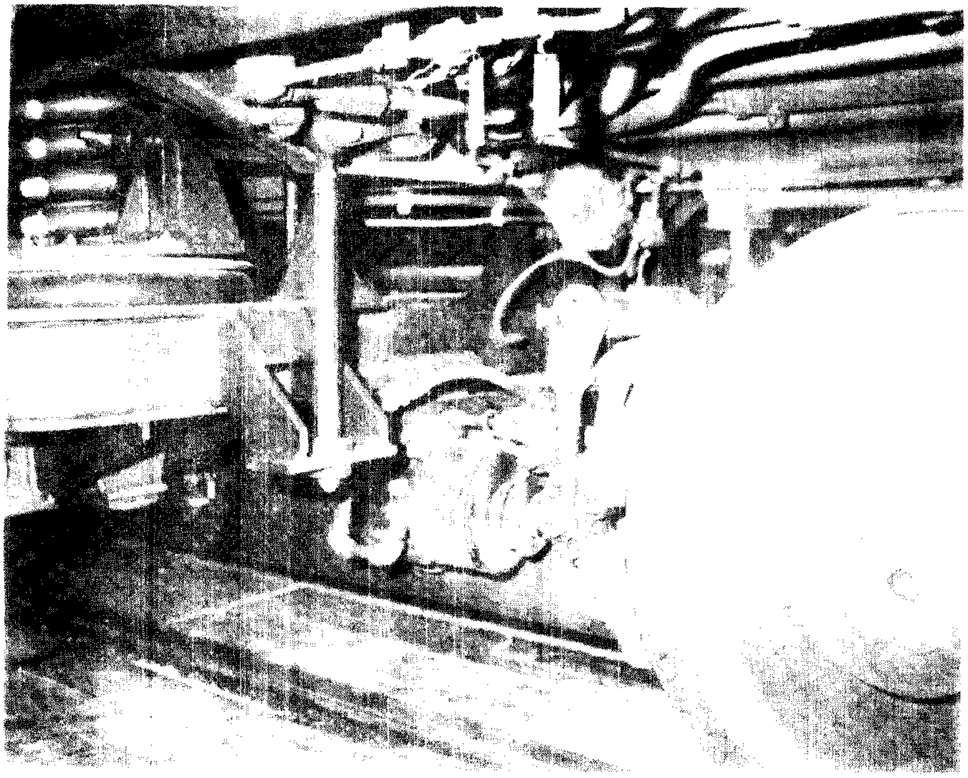

Figure 1-3. Knorr-Bremse Dual-Brake System

because it provides tangent track having 0.26-percent grade downhill from Station R 14.5 to Station R 19.6 in the direction of the test, a zero-percent grade from Station R 19.6 to Station R 24.3 in the direction of the test, and an 0.83-percent grade uphill from Station R 24.3 to Station R 25.5 in the direction of the test. The car/locomotive separation was made on the downhill portion of the test zone to allow the locomotive to make a good separation from the test car. The base test zone was 4,000 feet and provided minimal interference with and from other necessary operations at TTC. Automatic Location Detector (ALD) markers were installed every 50 feet for the first 1000 feet of the test zone and every 500 feet for the remainder because quick references were only needed in the breakaway zone. Otherwise, the ALD markers were only used for general reference.

The NEC simulation was performed over the entire RTT and covered 10,233 miles in a two-week period.

1.5 TEST PROCEDURES

1.5.1 GENERAL

The dual-brake systems developed by the brake manufacturers (under Amtrak supervision) were assembled at the Amtrak facility in Beech Grove, Indiana in accordance with the brake-manufacturers drawings and detailed technical supervision provided by Amtrak and the technical staff of the brake manufacturers.

The basic plumbing and the brackets required for installation of the brake hardware were designed and provided by the brake manufacturers. Final installation of this equipment including final modifications to the installation plans, the plumbing and the bracketry were performed at the TTC shops under the supervision of the brake manufacturers.

The test plans and the test instrumentation were developed by ENSCO, and reviewed and refined by all parties supporting the dual-brake evaluation program. The test was directed by ENSCO personnel and performed jointly by ENSCO and TTC personnel with technical support and direction provided by FRA, Amtrak and the participating brake manufacturers. The test results were developed by ENSCO with direct review and guidance by Amtrak. The basic test data were developed under the Amtrak contract and the test results report has been prepared under the FRA support contract as defined in the initial Task Plan of Action (TPA) for the Dual Brake Evaluation Program.

The car equipped with a standard disc brake (only) system (presently in use on Amfleet cars) was tested to define the standards for the dual-brake test. A single-car, cutaway test was performed on this car and the results were reviewed to confirm that the standard car was operating properly. The brake systems on each of the dual-braked cars were adjusted by the manufacturer so that these cars would match the brake-rate curves established as standard performance for an Amcoach equipped with disc brakes only. This project was not designed to improve the brake-rate of Amcoaches. Therefore, the performance of the new systems was adjusted to match the performance of the existing fleet of Amtrak cars. When the dual-braked cars are operated in Amfleet service, they will perform an equal share of consist braking. A car with a higher brake-rate cannot be operated in mixed service with cars having lesser brake-rates, since the cars with the higher brake-rate would take a larger share of the braking and would tend to overheat.

After the dual-brake systems were adjusted to match the braking rate of a standard car equipped with disc brakes only, a matrix of single-car, cutaway tests was performed on the three cars equipped with dual brakes. In each case, speed, braking distance, braking pressure and brake temperature were measured.

Each manufacturer was encouraged by Amtrak to test two different disc/tread ratios and to recommend what they thought would be the best ratio to meet NEC requirements. Cutaway tests were performed at each of the disc/tread ratios selected by the brake manufacturers. However, no tests were performed to verify the effective division of braking effort in the braking systems. Therefore, the braking ratios referred to in this report are nominal and are as provided by the technical staffs of the brake system manufacturers. The disc-to-tread ratios were 50/50 and 60/40 for the WABCO equipped car, 50/50 and 60/40 for the NYAB equipped car, and 60/40 and 70/30 for the Knorr equipped car.

After completion of the cutaway tests, the three dual-braked cars and the standard car were operated as a consist over 10,233 miles on a modified Northeast Corridor speed profile. The original speed profile had to be modified because of the operating characteristics of the DOT-001 locomotive. During the simulation, train operation was controlled to develop high brake-heating. The consist was operated at times with no locomotive braking and at other times with power braking.

The brake temperatures on the car equipped with WABCO dual brakes and the standard disc-brake (only) car were measured immediately after the consist stopped during the Northeast Corridor simulation test.

In addition to the normal braking-rate test, a special reduced-pressure, full-service braking test was performed on the standard (disc only) car. For this test, the normal full-service brake cylinder pressure was reduced from 68 to 55 psi by adjusting the 26-C control valve. A series of single-car cutaway tests were performed on the car equipped with standard disc brakes at the reduced brake pressure. The results were comparable to normal brake operation.

1.5.2 STOP DISTANCE TESTS

The stop distance tests were performed by towing the test car, releasing it from the locomotive and applying the brakes on the car by means of an onboard valve in the brake pipeline (Figure 1-4). Equipment on the car was used to measure brake pipe pressure, brake cylinder pressures, disc and tread temperatures, speed, elapsed time, location and stopping distance. This procedure was repeated for a series of specified speeds with the cars at half-service, full-service and emergency braking. The dual-brake-equipped cars were also tested at different disc-to-tread ratios selected by the brake manufacturers. The nominal disc-to-tread ratios were 50/50 and 60/40. The Knorr system was tested at 60/40 and 70/30.

1.5.3 NORTHEAST CORRIDOR SIMULATION

For the Northeast Corridor simulation, the four test cars were operated as a consist over 10,233 miles in a two-week period on the Railroad Test Track at the Transportation Test Center in Pueblo, CO. The consist simulated modified Northeast Corridor schedules and operations. The speed profile was stored in a computer memory onboard the locomotive. Actual distance traveled was measured by a wheel tachometer and input to the computer. The computer displayed the parameters that made it possible to simulate Northeast Corridor schedules and operations. The original and the modified speed/braking profiles are listed in Appendix G of the Test Events Report (ENSCO Report No. DOT-FR-80-21).

1.5.4 TESTING AT REDUCED FULL-SERVICE BRAKING PRESSURE

The full-service limiting pressure on the standard car was reduced from 68 to 55 psi. A series of full-service, stop distance tests were then performed on the car to determine whether the lower full-service limiting pressure on the disc brakes would result in stop distances that would satisfy Northeast Corridor block-distance requirements. Refer to Appendix E of this report for a complete description of these tests.

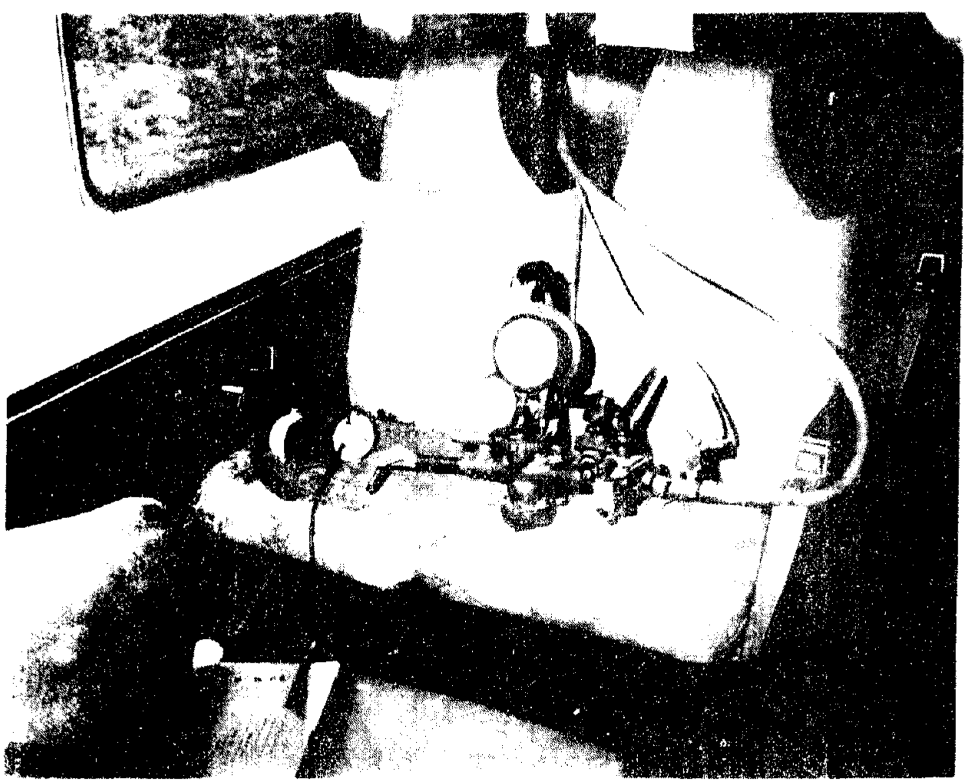

Figure 1-4. Special Brake Valve Mounted in Test Car

2.0 EQUIPMENT TESTED

2.1 GENERAL

The dual-brake test was performed using standard Amcoach equipment. The trucks on three standard Amcoaches were modified to add tread brakes to the standard disc-brake system used in the Amcoach fleet. Three brake manufacturers (WABCO, NYAB and Knorr) developed brake systems for this evaluation program using essentially standard components. Each manufacturer developed a tread-brake system that added a single brake shoe on each wheel of the Pioneer III truck. The equipments were quite different as shown in Figure 1-1 through 1-3.

The brake hardware was developed under the direct supervision and direction of Amtrak; therefore, descriptions of the brake equipment developed by the three manufacturers are not included as part of this report. The following general descriptions are included to help clarify the tests and the results obtained.

2.2 STANDARD CAR

The standard car (No. 21018) equipped with standard Knorr/Bremse disc brakes was used for comparison. This system uses two 27-inch discs per axle and operates normally at 68 psi brake cylinder pressure for full-service operation.

2.3 WABCO DUAL BRAKE SYSTEM

The Westinghouse Air Brake Company (WABCO) system (Figure 1-1) uses a standard tread-brake unit mounted on a heavy bracket welded to the Pioneer III tubular truck frame. The tread-brake units operate pneumatically, and the units selected for the test were compatible with the disc-brake system in that the same pressure could be applied to the disc cylinder and the tread brakes. This feature minimized the pressure regulators required to operate the dual-brake system. The WABCO system was originally developed to yield a 50/50 disc/tread ratio. When the units were modified to yield the alternate disc/tread ratio, the brake cylinders in the tread brake-system were modified to yield an approximate 60/40 disc/tread ratio.

2.4 NYAB DUAL BRAKE SYSTEM

The New York Air Brake (NYAB) tread-brake system (Figure 1-2) is suspended entirely from the brake hanger tubing. Therefore, no welding was required on the main truck frame to adapt the NYAB tread brakes to the standard truck. The tread-brake system is hydraulic and uses a single hydraulic cylinder on each side of the truck, i.e., two cylinders per truck. A pneumatic-to-hydraulic converter is required for this system. The NYAB system was operated with 50/50 and 60/40, disc/tread ratios.

2.5 KNORR DUAL BRAKE SYSTEM

The tread-brake system developed by Knorr/Bremse (Figure 1-3) uses pneumatic tread-brake units mounted by welding heavy brackets to the track frame. The mounting brackets for this system are similar to the brackets used for the WABCO system.

The Knorr tread-brake units are much lighter and smaller than the WABCO units. The Knorr disc/tread brakes were operated at 70/30, and 60/40 disc/tread ratios.

2.6 GENERAL OBSERVATIONS

All of the tread-brake units were compatible with the Pioneer III truck. It appears that all three companies can supply the equipment required to accomplish the dual-brake modification using existing equipment or equipment modified for this application.

3.0 DETAILED PROCEDURE FOR SINGLE-CAR CUTAWAY TESTS

3.1 TEST PROCEDURES

The procedure used in performing the single-car, stop-distance tests was to tow the test car to a speed sightly faster than the desired speed, cut the car away from the locomotive and apply the brakes. The basic parameters measured for each stop distance test were car speed, stopping distance and stopping time and brake pipe pressure. The specific sequence of events for each test were as follows:

- The coupled locomotive and test car stopped far enough from the test zone to allow the desired speed to be attained prior to entering the test zone.
- The car's main reservoir and air system were completely charged.
- The main reservoir and the brake pipe lines were isolated (bottled) from the locomotive.
- The consist then proceeded to the test zone at the desired speed.
- Prior to entering the test zone, the locomotive was uncoupled from the car by pulling the coupling pin using a pneumatic device operated by the locomotive engineer. Since the angle cocks to the main reservoir and the brake pipe had been closed, neither the car not the locomotive went into emergency braking when the air hose separated
- When test personnel onboard the test car were sure that uncoupling had occurred and that the car was in the test zone, the desired brake service application was made from inside the car by actuating a valve in the brake pipe line.
- The location of the car was recorded by equipment on the car and by a distance measuring back-up system that received tachometer pulses from the slip/slide magnetic pick-ups. Since the brake pipe pressure, the brake cylinder pressure, the time and the location were recorded on a strip-chart recorder, the location of brake application could be determined.

- Immediately after stopping (usually within five seconds), disc and wheel temperature measurements were made using a hand-held contact pyrometer. Normally, temperatures were measured and recorded in approximately three and one-half minutes. The location at which the car stopped was measured and by subtracting the location at which the brakes were applied, the total stopping distance was calculated.

- As soon as all measurements were completed, the locomotive was coupled to the car and the air systems on the car were recharged while enroute to the location where the next run would begin.

3.2 TEST EQUIPMENT

The test equipment used for the single-car tests consisted of the following:

- Automatic Location Detector (ALD): This equipment sensed the presence of metal targets located wayside at known and regular intervals throughout the test zone.

- Speed and Distance Unit: This equipment received pulses from the magnetic sensors in the car's slip/slide system. Knowing the number of pulses per wheel revolution and the wheel circumference, the speed and distance traveled was calculated.

- Pressure Transducers: Pressure transducers were installed to measure brake pipe pressure, disc brake cylinder pressure and tread brake cylinder pressure on the B-truck of each car.

- Optical Pyrometers: Optical infra-red pyrometers were mounted to measure disc brake and wheel tread surface temperatures on the L_1 position on each car.

- Speed: A radar gun was mounted on the car to provide a back-up speed measurement. The radar-gun-speed was found to be inaccurate and was not used (nor needed) for this test.

- Time: A precision one-second time measurement was used to provide stop time.

- Slip/Slide Detection: The output of the car's slip/slide system was monitored and used as a signal for wheel slip for the entire test.

- Strip Chart Recorder: An eight-channel Brush chart recorder provided by TTC was used to record all of the preceding data.

- Contact Pyrometer: Two contact pyrometers were available for disc brake and wheel tread temperature measurements when the car came to a stop. It was found that it was faster to use a single pyrometer with one observer and one recorder than two pyrometers with each person measuring and recording.

- Steel Tape: The tape was used to measure the car's location after the car had come to a complete stop.

- Auxilliary Power Unit (APU): TTC furnished a 45-KW diesel generator which was mounted in the vestibule of each test car. This generator was used to supply hotel power during the test.

- Backup APU: A 3.5-KW gasoline powered generator was used as backup power for the test instrumentation only in case of failure of the 45-KW generator.

3.3 ANALYSIS TECHNIQUES

The data analysis associated with the stop distance tests consisted primarily of taking measurements from the strip chart recorder.

Figure 3-1 is a simulated overlay of the data traces for the brake-pipe pressure and the disc-brake cylinder pressure. By definition, the speed of each test run was the speed of the car just prior to (approximately 0.1 second) brake handle movement, point A in Figure 3-1. Distance and time were measured from the instant of equipment time of brake application, point D in Figure 3-1. The equivalent brake application approach was

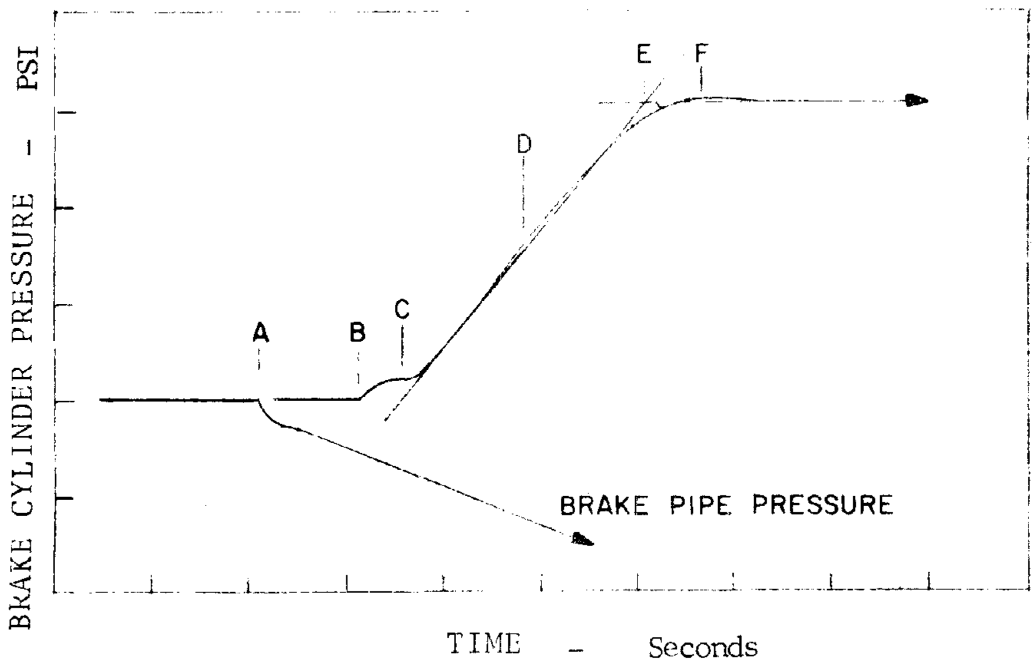

Figure 3-1. Simulated Overlay of Data Traces for Brake Pipe Pressure and Disc-Brake-Cylinder Pressure

where:

A = Time of Brake Handle Movement

B = Time of Brake Cylinder Pressure Change

C = Equivalent Time of Brake Cylinder Pressure Change

D = Equivalent Brake Application Time

E = Equivalent Time of Maximum Brake Cylinder Pressure

F = Time of Maximum Brake Cylinder Pressure used to minimize brake-cylinder-pressure build-up variations among the cars. The equivalent brake application time was calculated in accordance with the procedures described in "Engineering Design of Railway Brake Systems" by The Air Brake Association (pp. II.16-17). Other points in Figure 3-1 are presented in order to show the relative time delays of similar events as they occurred, on the average for each car.

Temperatures recorded by the optical pyrometers are non-exact absolute temperatures but are good relative indications of temperature. Therefore, maximum temperatures measured by these instruments and listed in this report have been adjusted so that the temperature yielded by the optical pyrometer and the contact pyrometer are equal at the time temperatures were measured with the contact pyrometer. This may not be an exact procedure, but due to the variables associated with optical pyrometry and the circumstances that existed during testing (primarily the exact emissivity of the disc and the wheels and how it changed), it seems that the temperature data is very useful and relatively accurate (to within 25 or 50 degrees Fahrenheit).

Brake cylinder pressure did not remain constant during stops for any of the cars. The brake cylinder pressure used was the average pressure measured through the dominant portion of each stop. The Test Run Data Sheets provided in the Test Events Report (ENSCO Report DOT-FR-80-21) give the disc and brake cylinder pressures beginning with the equivalent maximum brake cylinder pressure (point E in Figure 3-1) and at ten second intervals thereafter with the last point being the brake cylinder pressure at stop time.

Stop distance data was plotted for each car, each brake service and each disc to tread ratio as a function of speed. A mathematical equation was derived for each graph of the form:

$$\text{Distance} = A\ (\text{Speed}^{B})$$

where A and B are constants derived from the test data using curve fitting analysis techniques.

In every case the value of (B) was found to be very nearly 2.0. This is in good agreement with the common understanding that stopping distance is proportional to speed squared. Therefore, it was felt that it would be more in keeping with common practive to define the equation in the following terms.

$$\text{Distance} = A_0 + A_1 \text{ (Speed)} + A_2 \text{ (Speed}^2\text{)}$$

where distance is measured in feet and speed is measured in miles per hour.* This form, promoted a better fit to the observed data in the range of test speeds. However, at low speeds it is possible for this equation to pass through a non-zero value at zero speed and can have stop distances that increase as speed decreases. It seems that at least two equations are required. One equation to describe the stop distance from zero to 60-80 mph and another equation for speeds above 60-80 mph. For presentation purposes, however, the derived equation does fit the observed data quite well in the 40 to 120 mph range. It was also observed that quantity A_2 is 40 times more significant than A_1 at 40 mph and 120 times more significant at 120 mph.

Instantaneous deceleration data were taken from the speed data on the strip chart recorder. The technique used was simply to overlay a straightedge on the speed trace to define points at which the rate-of-change of speed changed. It was observed that these points generally occurred at approximately the same speed, regardless of the initial speed and that, in general, deceleration was also directly related to speed regardless of initial speed.

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*A_0, A_1 and A_2 are constants derived from the test data using curve fitting analysis techniques.

4.0 NORTHEAST CORRIDOR SIMULATION

4.1 PROCEDURE

The procedure followed in the NEC simulation was basically to operate the standard car and the three dual-brake equipped cars over a two-week period, or approximately 10,000 miles, in a manner that would duplicate the train handling and time-table of the Northeast Corridor (NEC).

4.2 EQUIPMENT

The equipment used for the Northeast Corridor simulation consisted of the locomotive DOT-001 and the four test cars, 21018, 21044, 21063 and 21087. A speed profile simulator was fabricated and used during this test.

The simulator displayed the parameters that made it possible to maintain the NEC schedule. Data displayed was the current location (milepost), the current speed limit, the elapsed time, the milepost location of the next speed change, the next speed, and the scheduled time of the speed change. The simulator processed tachometer pulses from the locomotive speed system to compute distance traveled and compared that distance to the speed profile stored in its memory. When the two distances were equal the engineer was alerted and all displays updated. In addition, a sequence of warning lights would be lighted to aid the engineer so that he could simply monitor the warning lights as a speed change was approaching. When the last light was turned on, the proper action could be taken. Figure 4-1 is a sample of the information printed by the simulator as a record of each NEC simulation run.

```
AHEAD   00:08:17

AT MILE 108.10

POSTED SPEED CHANGED
   FROM  105
  TO     120

TRIP ELAPSED TIME WAS
      01:07:29
IT SHOULD HAVE BEEN
     01:15:46


AHEAD   00:08:01

AT MILE 110.58

POSTED SPEED CHANGED
   FROM  120
  TO      90

TRIP ELAPSED TIME WAS
      01:09:06
IT SHOULD HAVE BEEN
     01:17:07
```

Figure 4-1. Sample Output of Northeast Corridor Speed Profile Indicator

5.0 REDUCED FULL SERVICE LIMITING TEST

The procedure used for this series of tests was identical to the procedures described in Section 3.0. The only difference was that the full-service limiting pressure of the 26-C valve was set at 55 psi instead of the standard 68 psi.

6.0 TEST RESULTS

6.1 SINGLE CAR STOP-DISTANCE TESTS

The results of the single car stop distance tests are shown graphically in Figures A-1 through A-20 in Appendix A of this report. Figures 6-1, 6-2, 6-3 show the overlayed, derived mathematical curves for all the cars at half - full - and emergency service brake applications. It is evident that the dual-braked cars do not match the standard car very well for half-service braking (with the exception of Car No. 21044 at 50/50 disc/tread ratio). This might be caused by the volume of air required by the dual-brake system being too large. Therefore, the slack in the brake system is not taken up completely. The dual-braked cars matched the standard car quite well for full-service and emergency-service brake application. Figures B-1 through B-83 in Appendix B of this report show typical speed profiles of each car stopping from different speeds at full-service and emergency-service braking, and at different disc/tread ratios where applicable. Figures 6-4 through 6-17 show composites of the speed profile results for each car at full-service and emergency-service braking for each different disc/tread ratio. Figures C-1 through C-27 in Appendix C of this report show the peak temperatures and the stop temperatures observed at each test speed, brake service and disc/tread ratio. It is apparent that the temperatures observed on the dual-braked cars are significantly lower than the temperatures observed on the standard car under identical conditions.

Tables D-1 through D-120 in Appendix D to this report list specific deceleration data for each of the single-car, stop distance tests. The deceleration results are also shown in Figures 6-4 through 6-17.

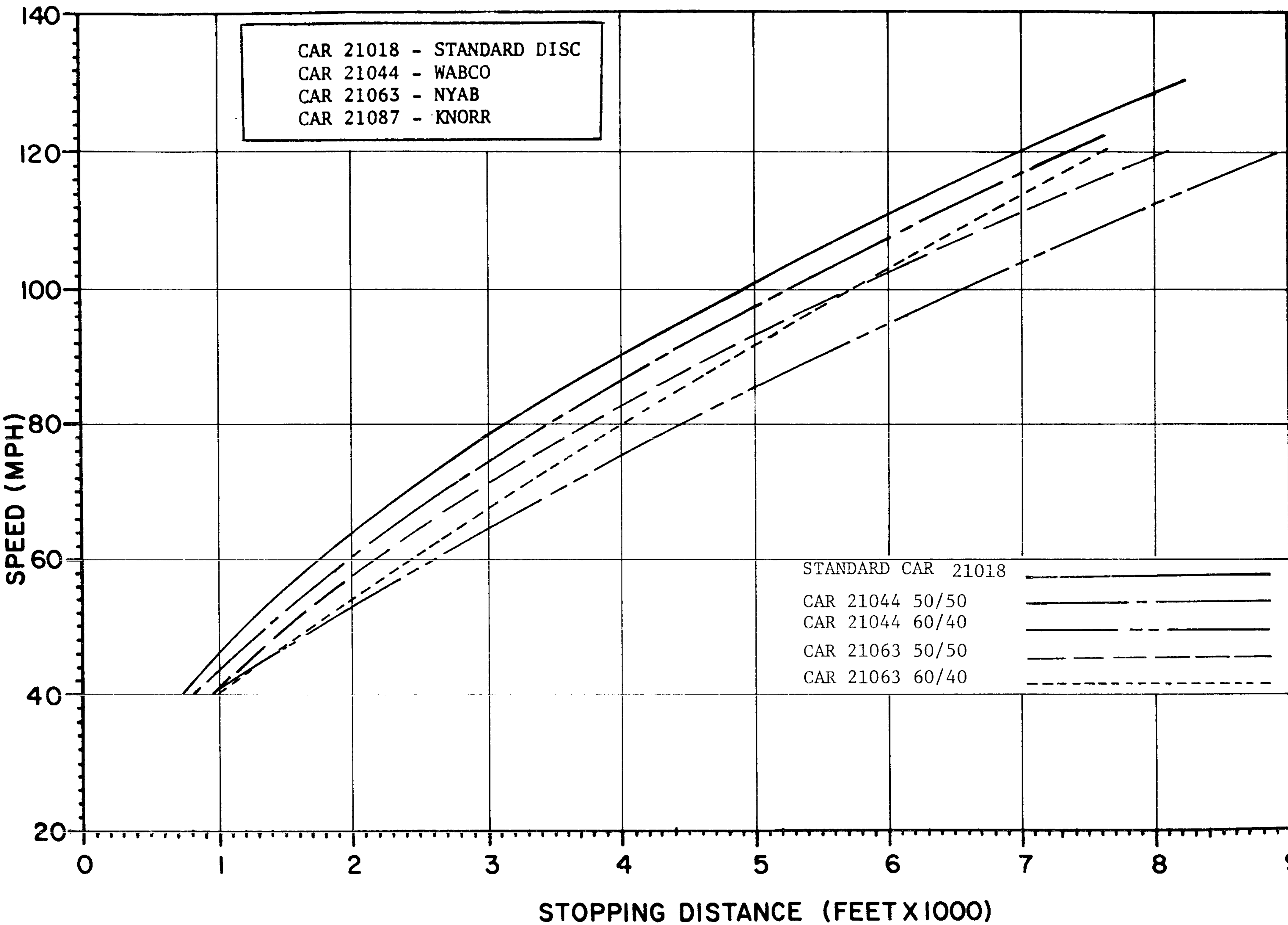

Figure 6-1. Stopping Distance vs. Speed - Half Service Braking

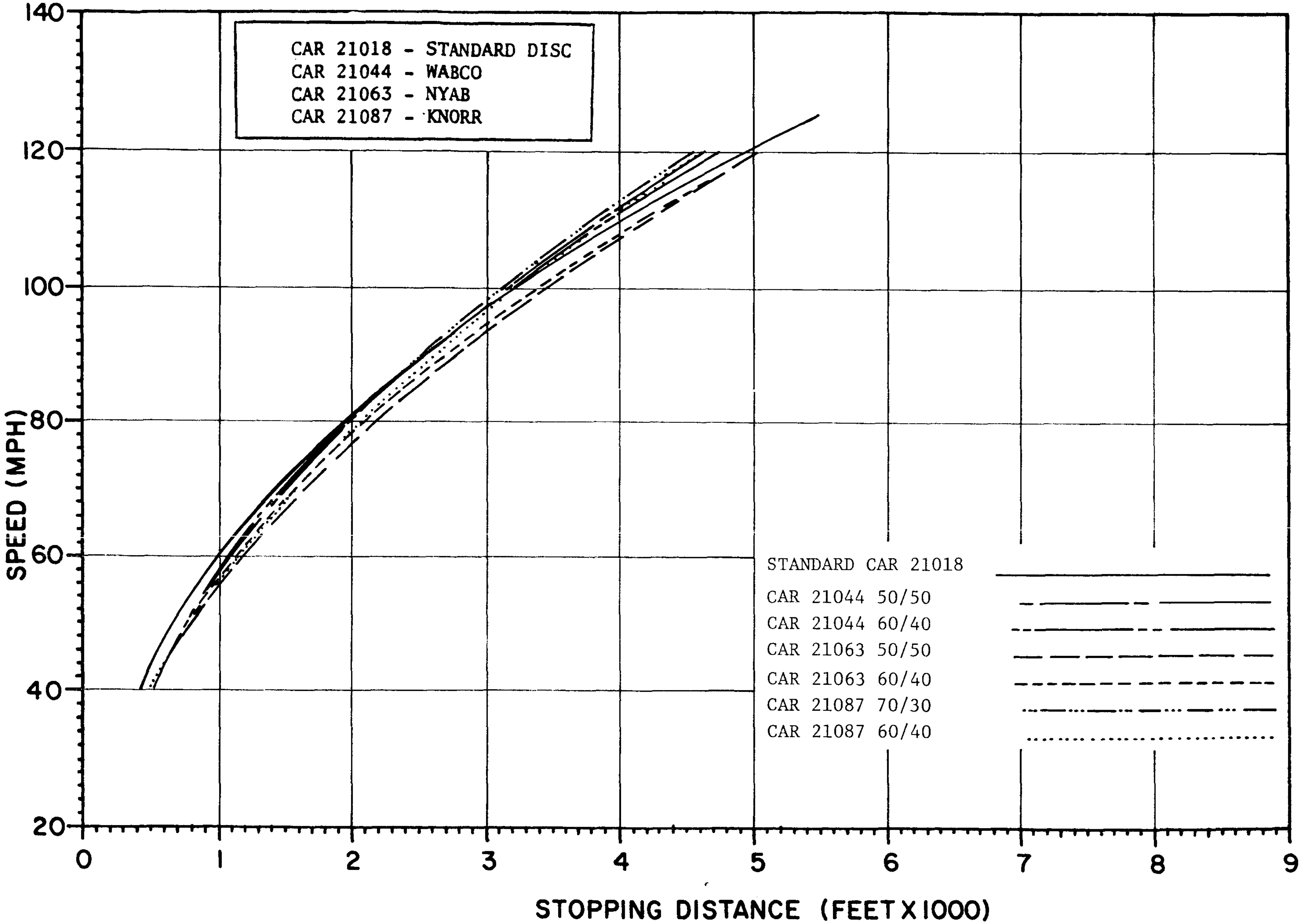

Figure 6-2. Stopping Distance vs. Speed - Full- Service Braking

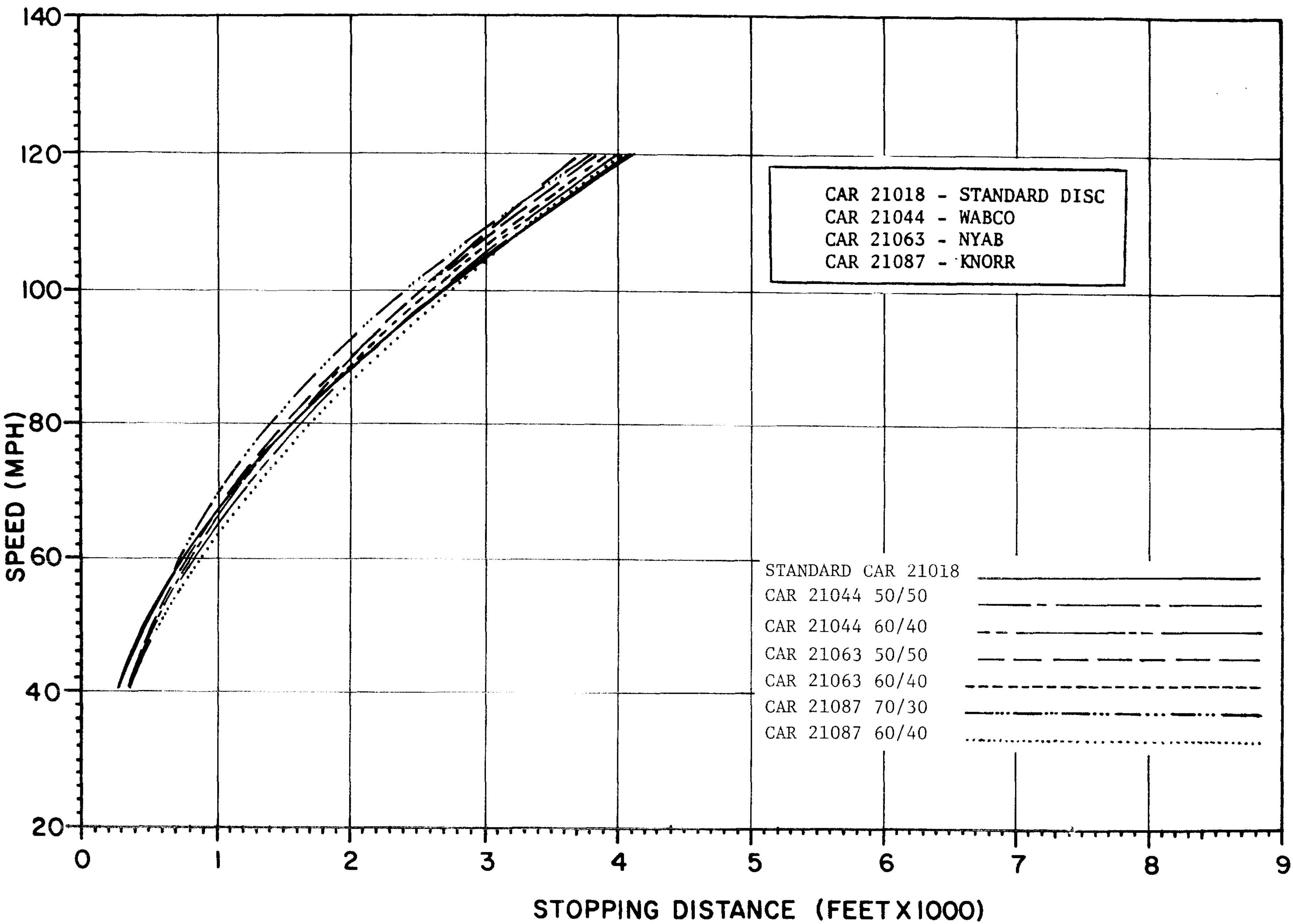

Figure 6-3. Stopping Distance vs. Speed Emergency-Service Braking

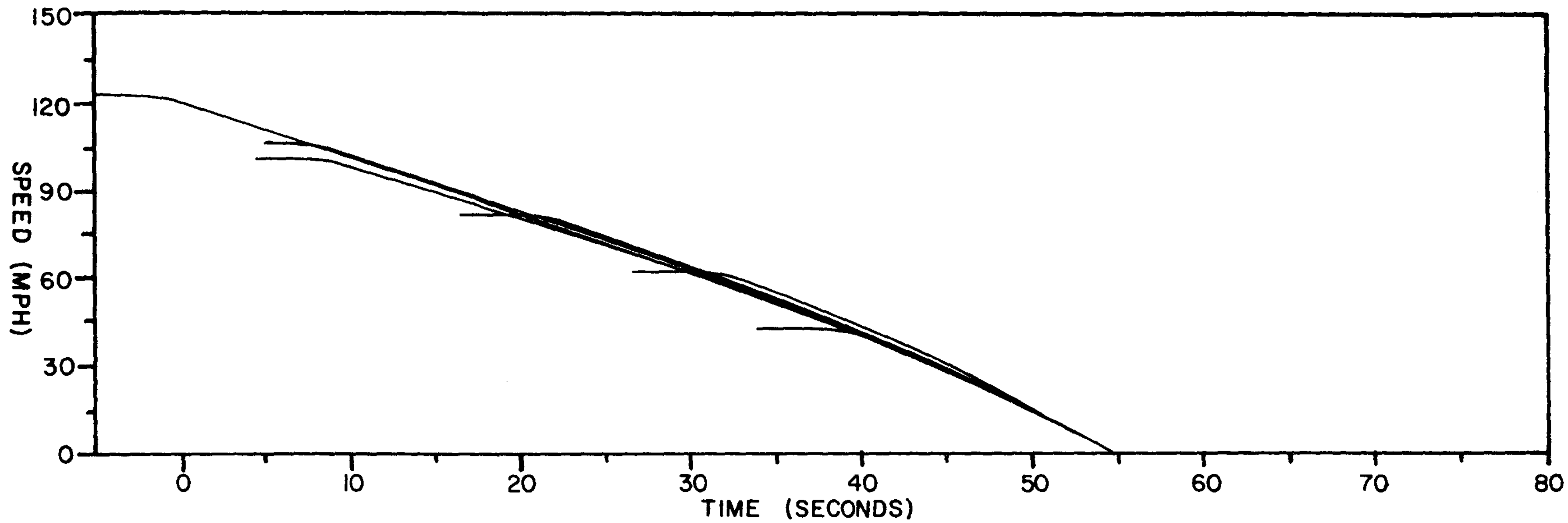

Figure 6-4. Speed Profile Standard Car (No. 21018) From Different Speeds - Full Service Braking.

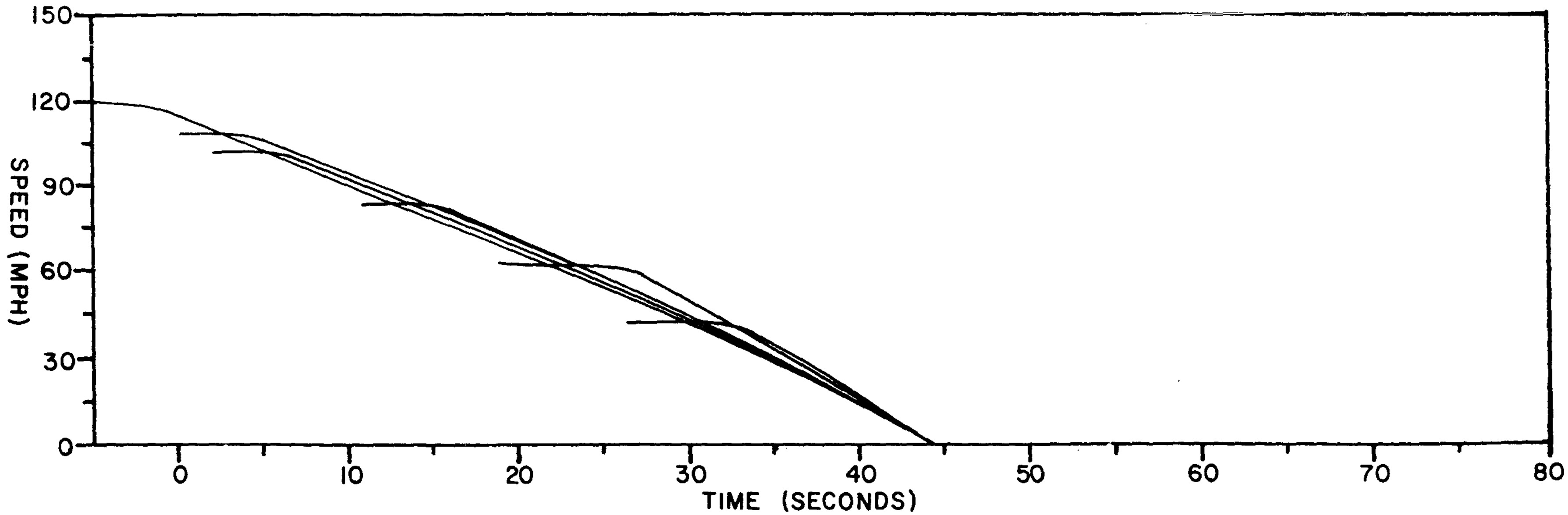

Figure 6-5. Speed Profile Standard Car (No. 21018) From Different Speeds - Emergency Service Braking

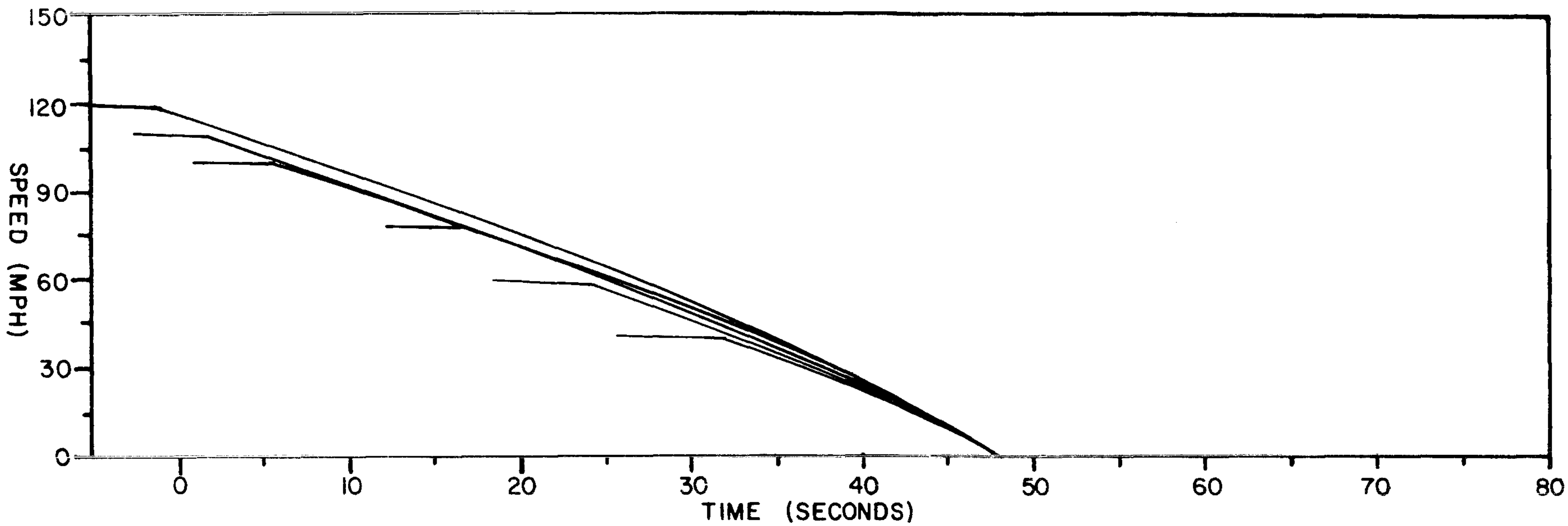

Figure 6-6. Speed Profile Car No. 21044 From Different Speeds - Full Service Braking (50/50 Disc/Tread Ratio)

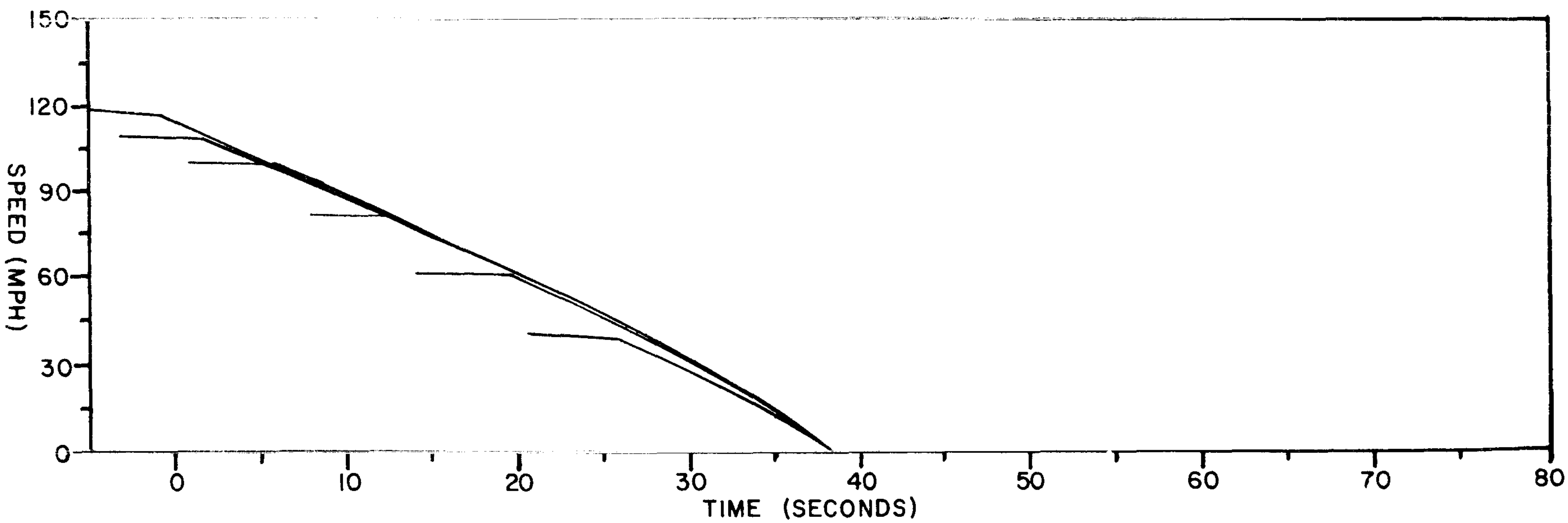

Figure 6-7. Speed Profile Car No. 21044 From Different Speeds - Emergency Service Braking (50/50 Disc/Tread Ratio)

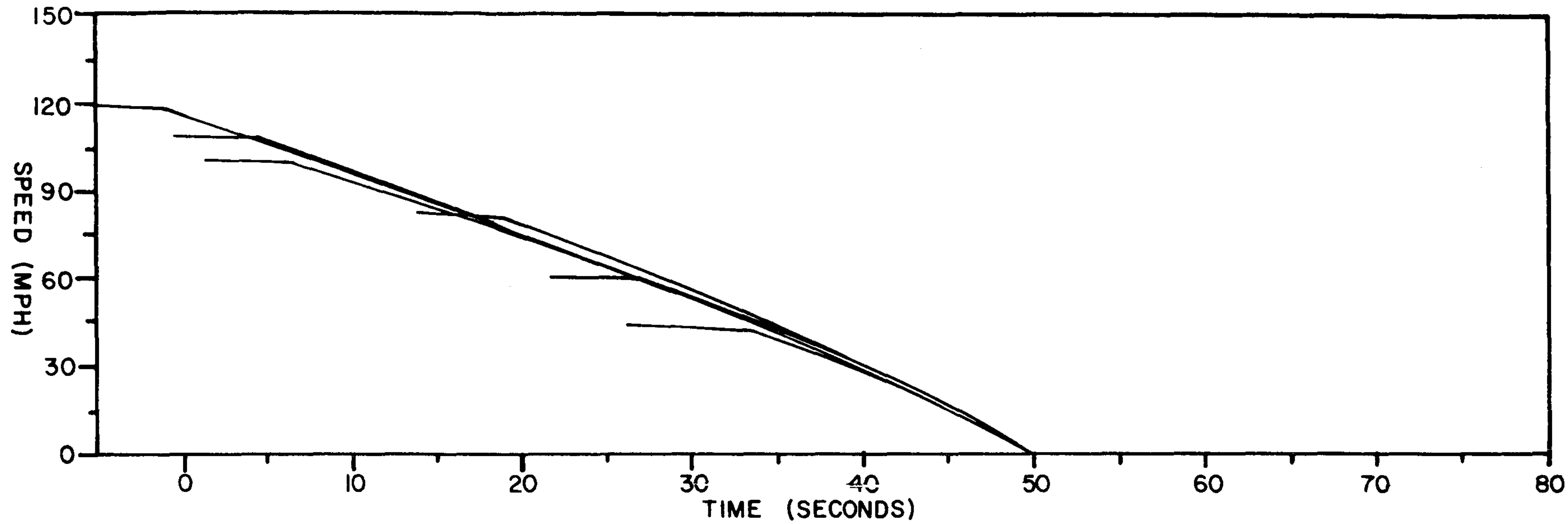

Figure 6-8. Speed Profile Car No. 21044 From Different Speeds - Full Service Braking (60/40 Disc/Tread Ratio)

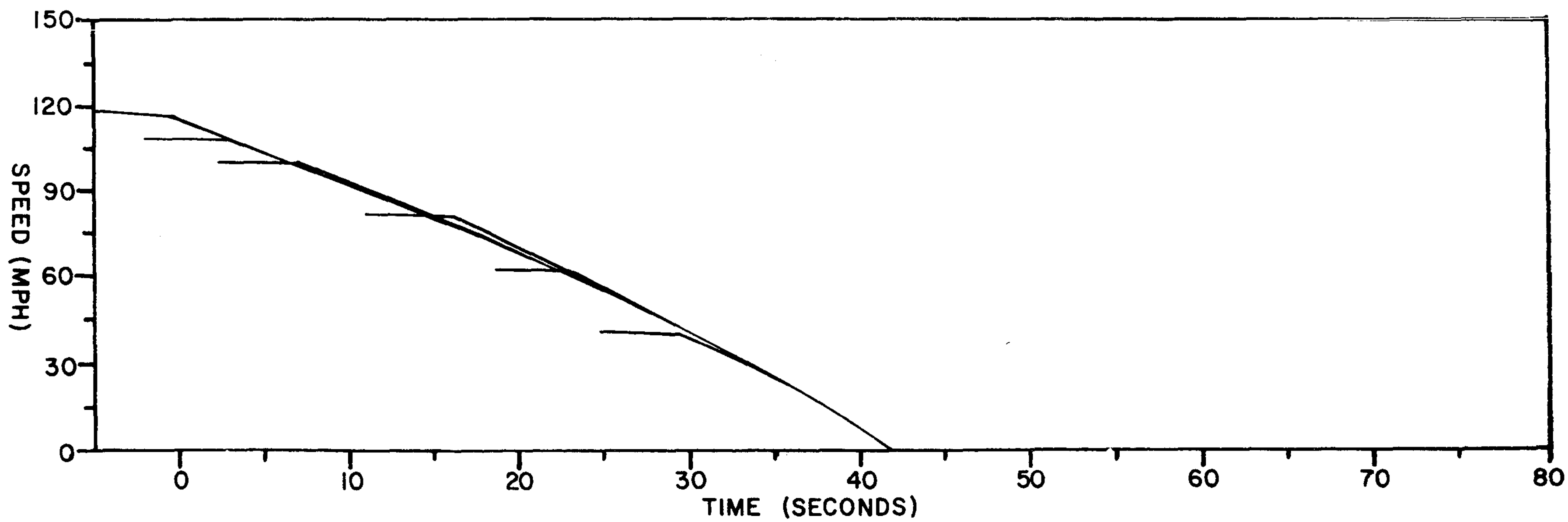

Figure 6-9. Speed Profile Car No. 21044 From Different Speeds - Emergency Service Braking (60/40 Disc/Tread Ratio)

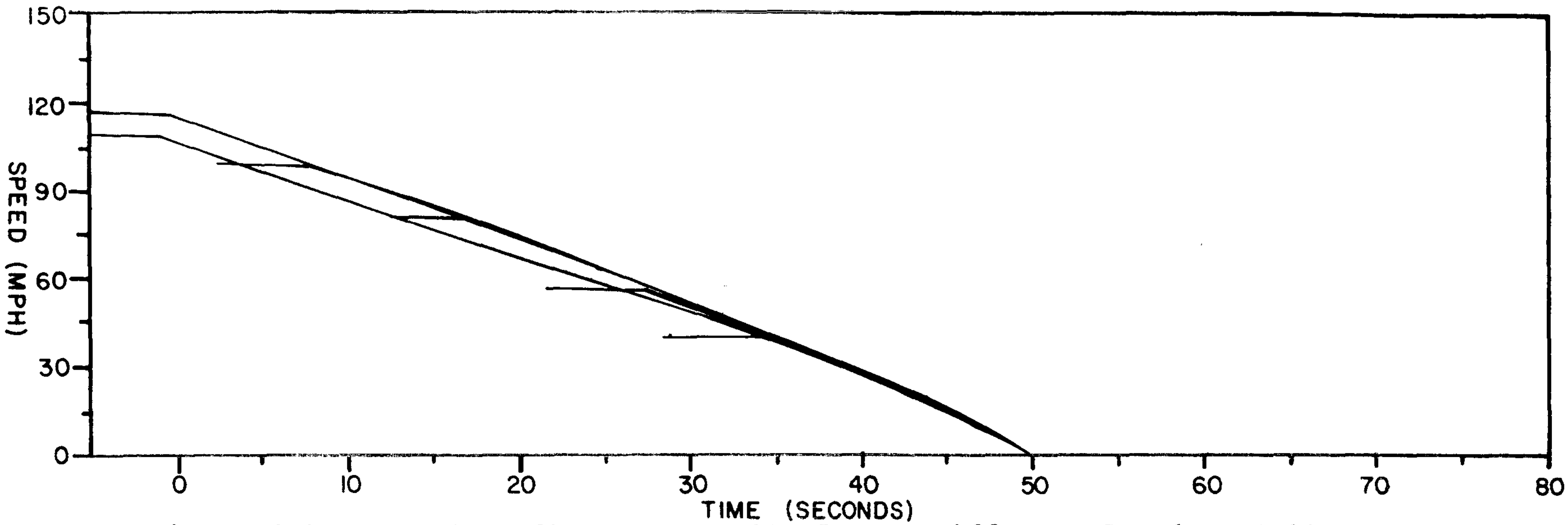

Figure 6-10. Speed Profile Car No. 21063 From Different Speeds - Full Service Braking (50/50 Disc/Tread Ratio)

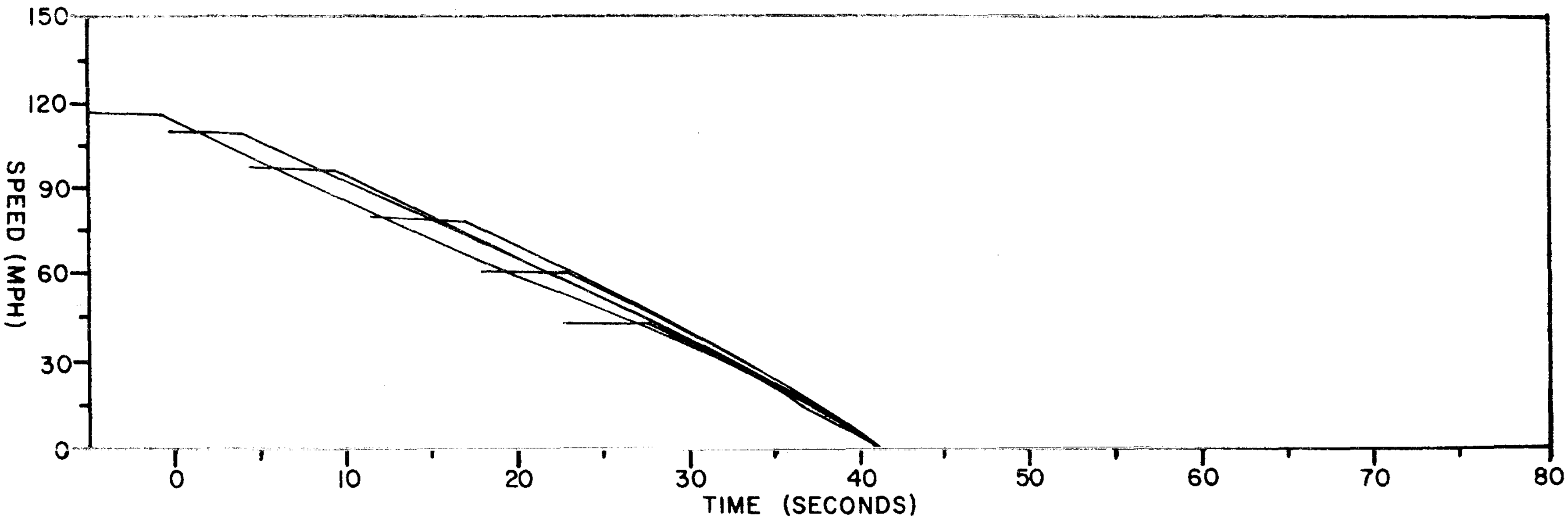

Figure 6-11. Speed Profile Car No. 21063 From Different Speeds - Emergency Service Braking (50/50 Disc/Tread Ratio)

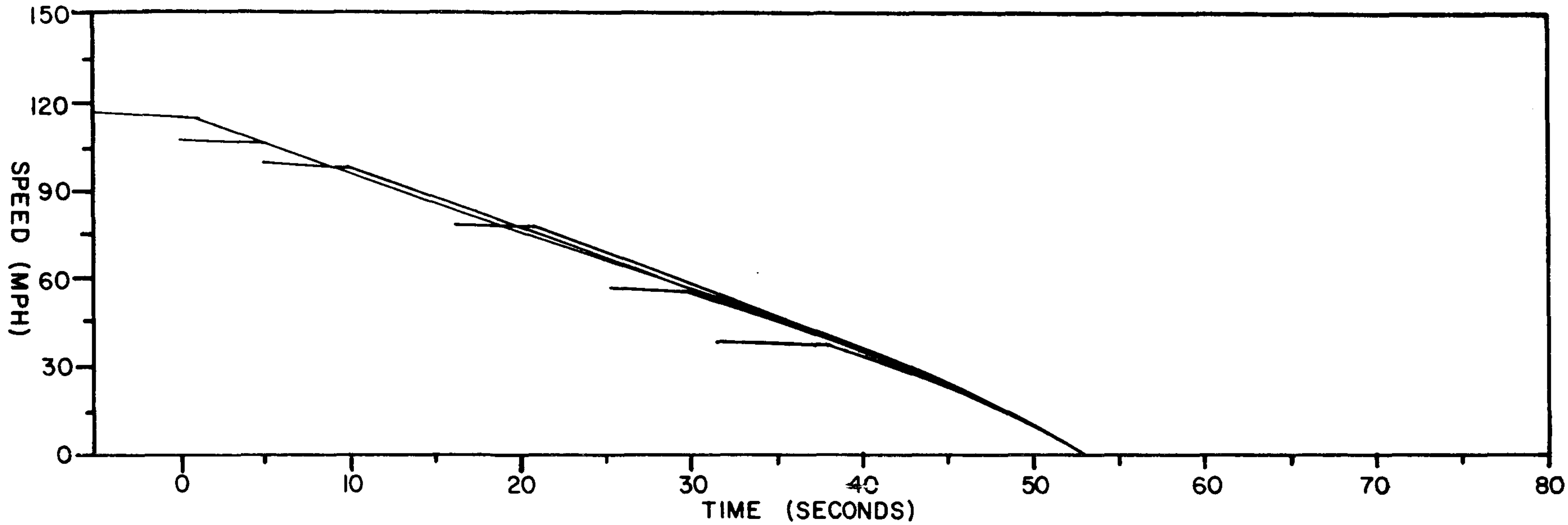

Figure 6-12. Speed Profile Car No. 21063 From Different Speeds - Full Service Braking (60/40 Disc/Tread Ratio)

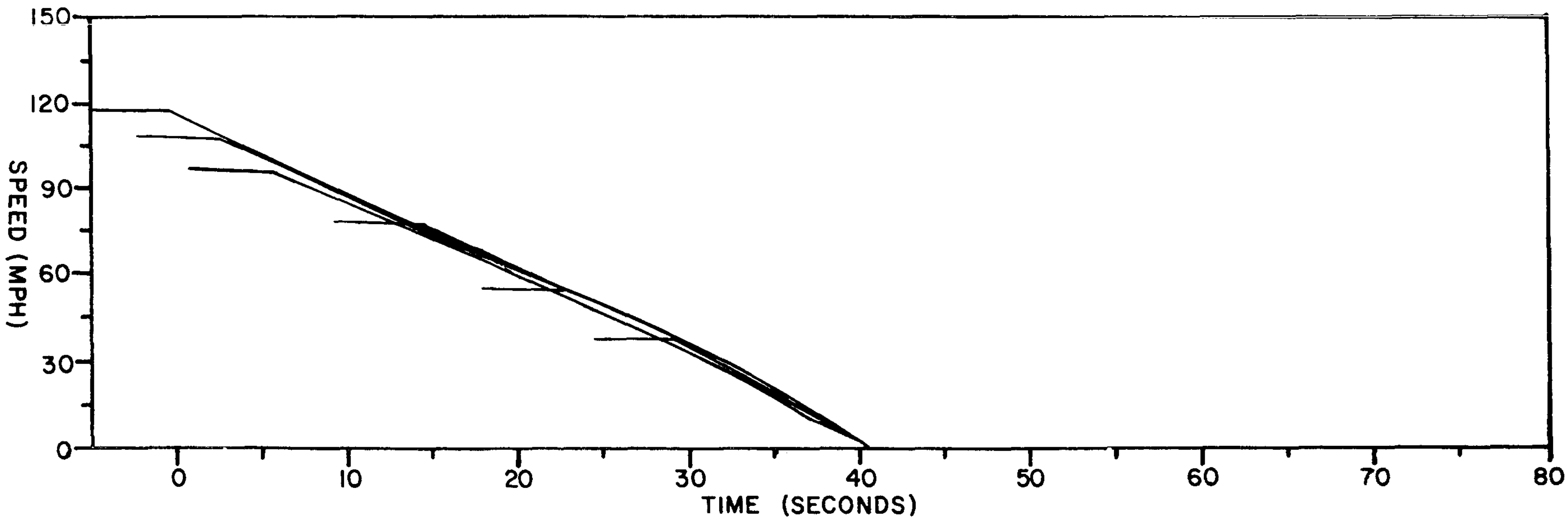

Figure 6-13. Speed Profile Car No. 21063 From Different Speeds - Emergency Service Braking (60/40 Disc/Tread Ratio)

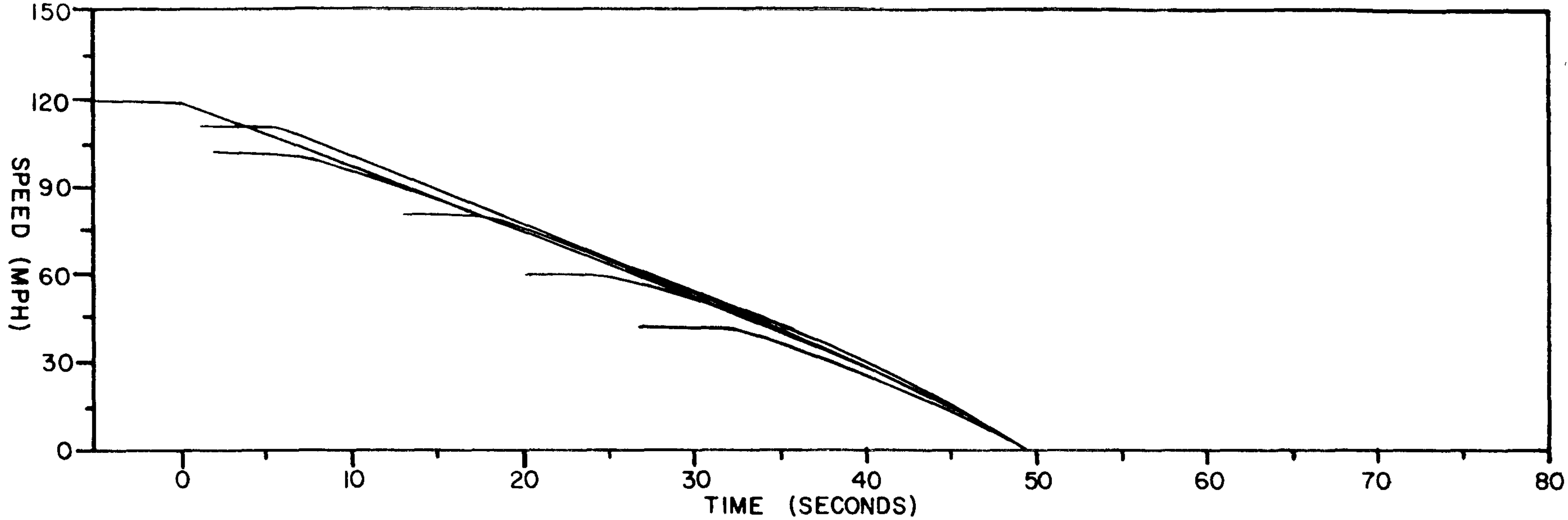

Figure 6-14. Speed Profile Car No. 21087 From Different Speeds - Full Service Braking (70/30 Disc/Tread Ratio)

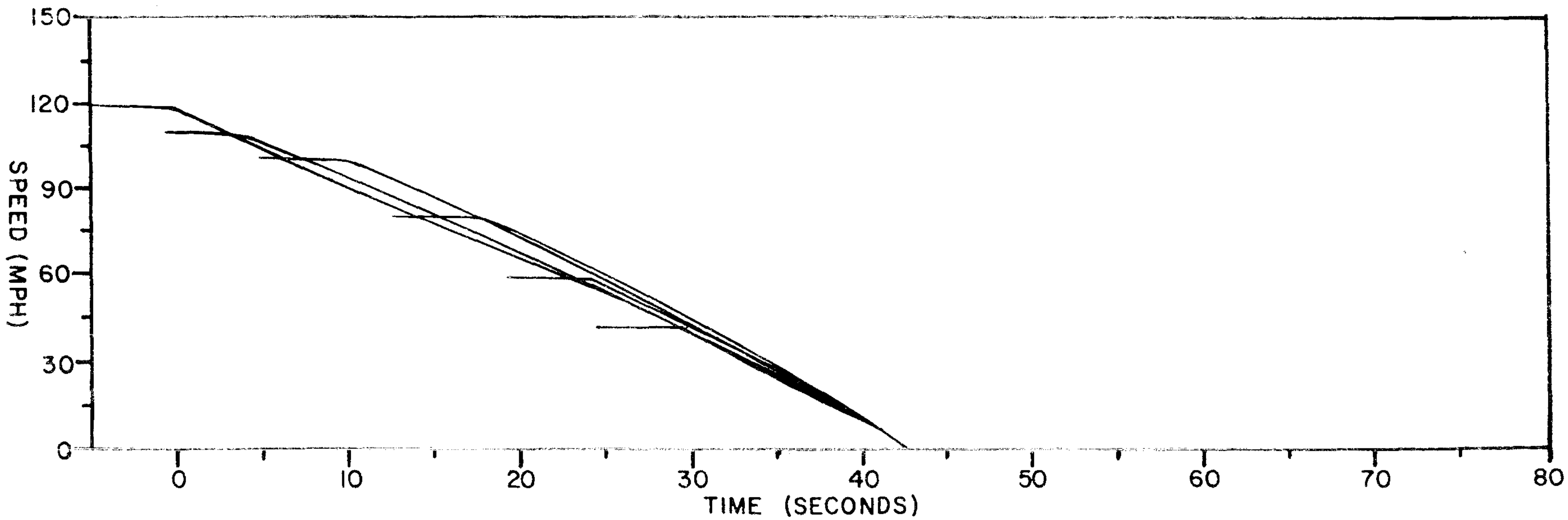

Figure 6-15. Speed Profile Car No. 21087 From Different Speeds - Emergency Service Braking (70/30 Disc/Tread Ratio)

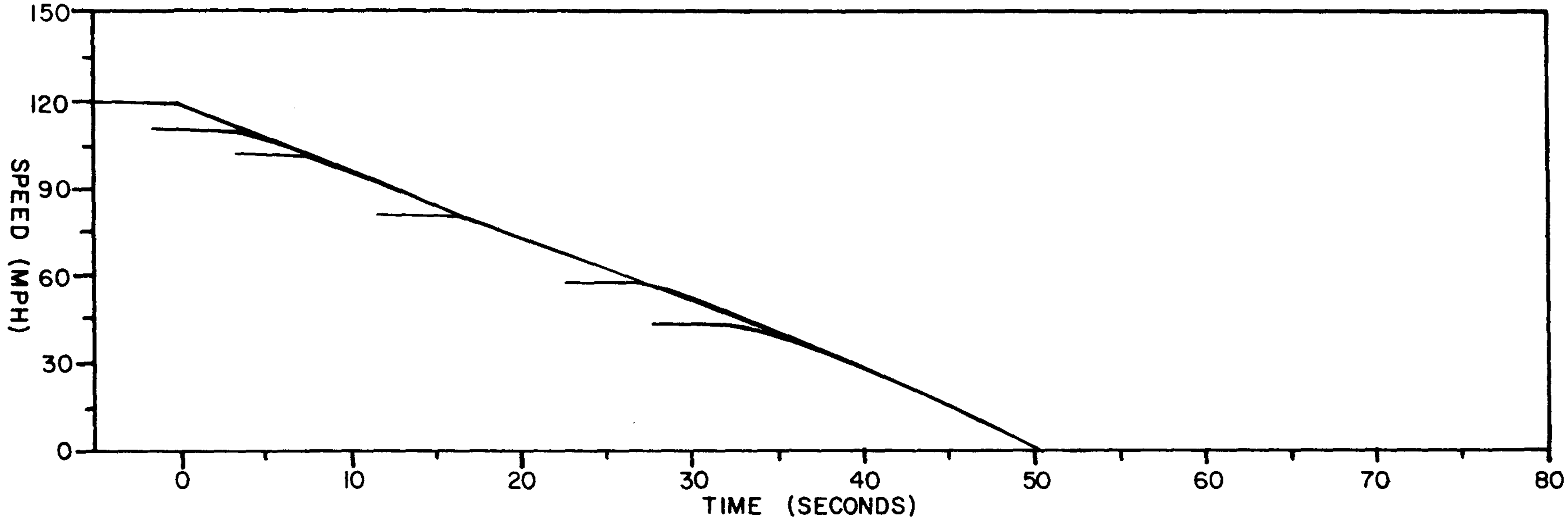

Figure 6-16. Speed Profile Car No. 21087 From Different Speeds - Full Service Braking (60/40 Disc/Tread Ratio)

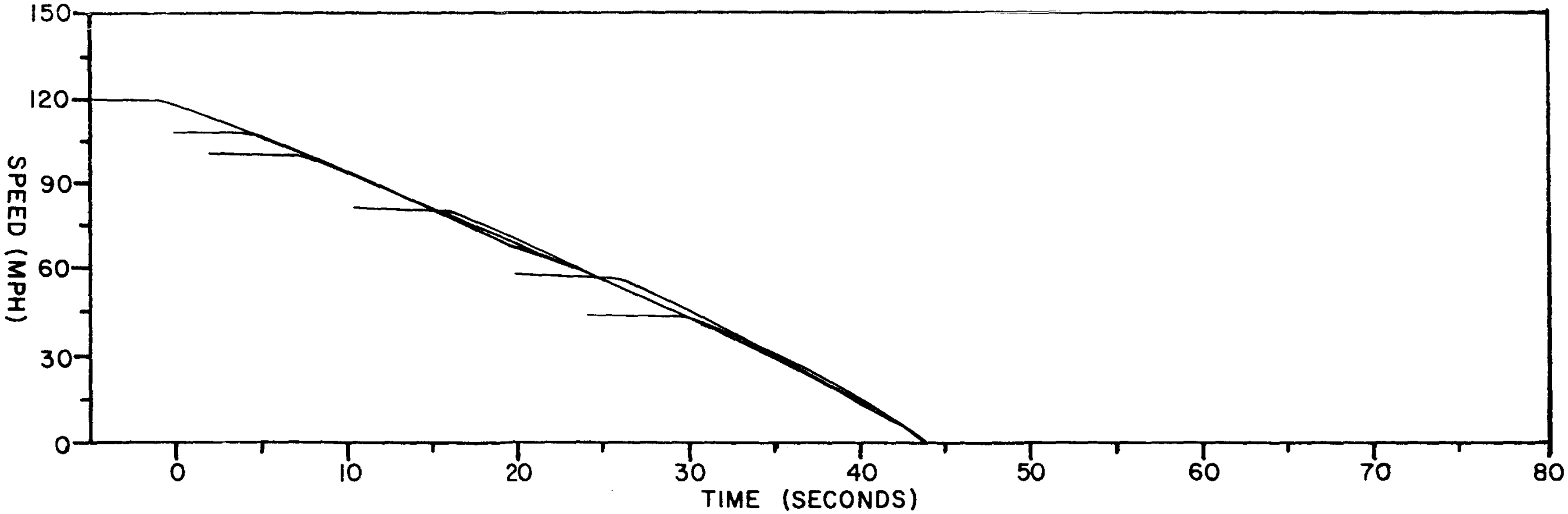

Figure 6-17. Speed Profile Car No. 21087 From Different Speeds - Emergency Service Braking (60/40 Disc/Tread Ratio)

6.2 NORTHEAST CORRIDOR SIMULATION

During the NEC simulation, a total of 10,233 miles were accumulated running the four test cars as a consist over a two-week period. No problems were experienced with the dual-brake systems that would preclude their use on the Northeast Corridor for further in-service evaluation. Temperature data were measured on NEC profiles (original and modified) under normal and power braking conditions. These temperature data are listed in Table 6-1. The data show that the brake temperatures for the dual-braked cars were quite satisfactory even under power braking.

6.3 REDUCED-PRESSURE, FULL-SERVICE BRAKING TESTS

The stop distances as a function of speed for the reduced full-service brake applications are shown in Figure A-20. The stop distance for this test is approximately 700 feet longer than the normal full-service stop distance at 120 mph. The significant difference is that the reduced full-service stops resulted in much lower deceleration and consequently lower adhesion demands at lower speeds. This is a significant result in that this lower adhesion demand is nearer the available adhesion on the NEC during normal operating conditions. This should reduce the occurrence of wheel slip and the associated wheel maintenance costs while providing braking effort sufficient to satisfy NEC signal-block distances. The reduction of the full-service limiting pressure could serve as a temporary solution to wheel slip until dual-brake systems are installed on all Amcoaches.

Figure C-3 shows the temperature data measured during the reduced brake-pressure tests.

Tables D-26 through D-35 list the deceleration data derived from the strip-chart recordings obtained on these tests.

6.4 TREAD AND WHEEL-TREAD TEMPERATURES

Both tread and wheel-tread temperatures were measured as part of the data collected during the single-car cutaway tests on the standard car and all three of the dual-braked cars. The temperatures were measured while the cars were moving through the test zone with the brakes applied and immediately after the cars rolled to a stop. Temperature measurements made while the cars were moving, were made with a pair of optical pyrometers mounted to the truck frame and focused on the wheel tread and the disc as described in Section 3.2. After the car stopped, wheel-tread and disc temperatures were also measured using a hand-held, thermocouple pyrometer. The results of the pyrometer measurements are shown on the graphs in Figures C-1 through C-27 in Appendix C of this report.

These graphs show the actual test results and the approximate trends in the temperature measurements by means of best-fit curves through the data points. The graphs in Figures 6-18 through 6-25 show summaries of the results of the infrared optical pyrometer measurements, and the contact pyrometer measurements (after stopping) for each of the dual-braked cars for full-service and emergency-service braking. Figures 6-26 through 6-31 show the combined temperature measurements to illustrate the effect of varying the disc/tread brake ratio. A significant result is that the trends in these results are independent of the cars.

The combined curves (Figures 6-26 through 6-31) show that the temperature results are consistent despite the scatter in the raw data. The disc-brake temperatures are more consistent than the wheel-tread temperatures, and the data obtained from the hand-held pyrometers (after the car stopped) are somewhat more consistent than the data obtained from the optical pryometers while the car was moving.

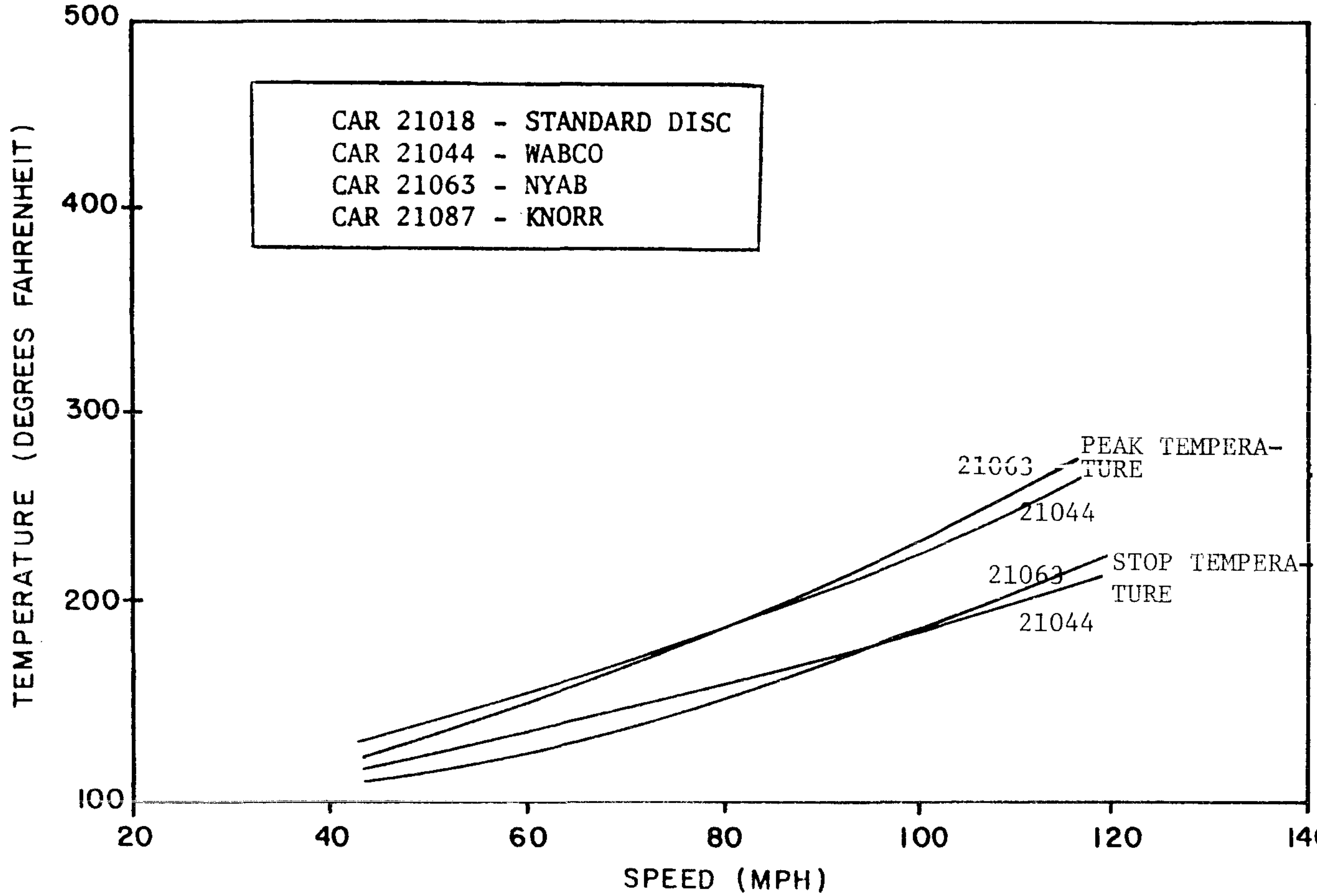

Figure 6-18. Summary of Results - Disc Temperature Measurements - Car Nos. 21044 and 21063 - Full Service Braking - 50/50 Disc/Tread Ratio

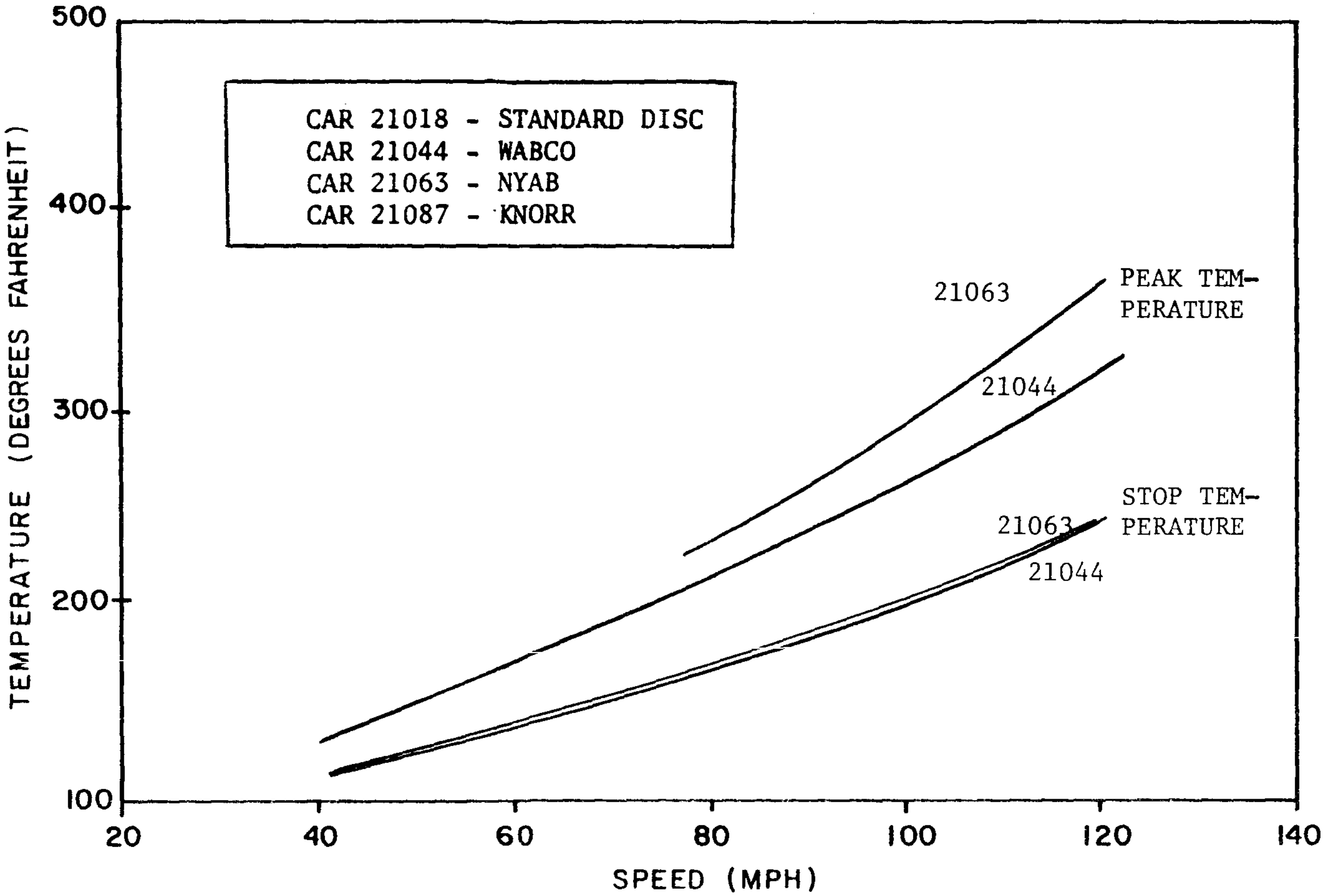

Figure 6-19. Summary of Results - Tread Temperature Measurements - Car Nos. 21044 and 21063 - Full Service Braking - 50/50 Disc/Tread Ratio

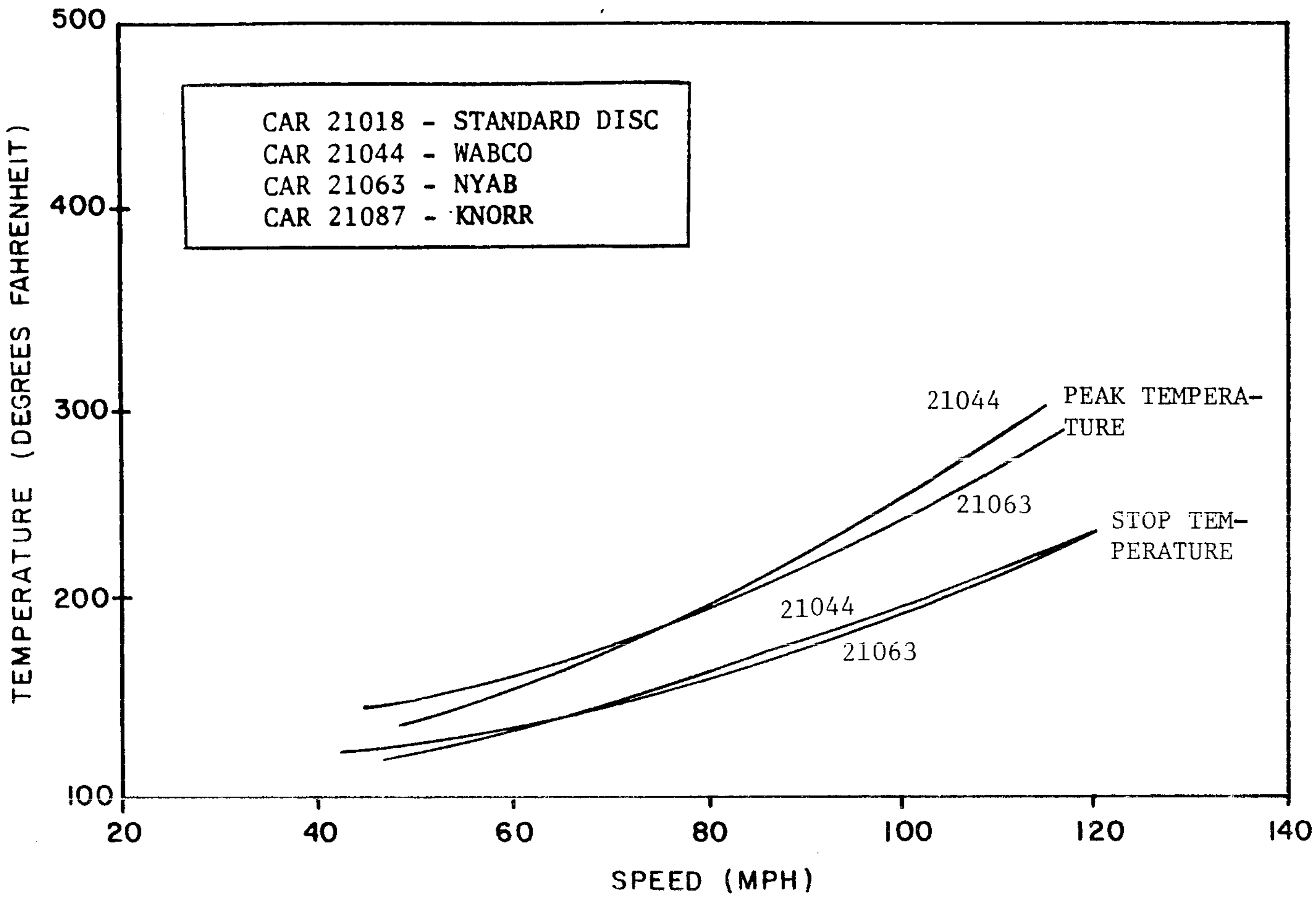

Figure 6-20. Summary of Results - Disc Temperature Measurements - Car Nos. 21044 and 21063 - Emergency Braking - 50/50 Disc/Tread Ratio

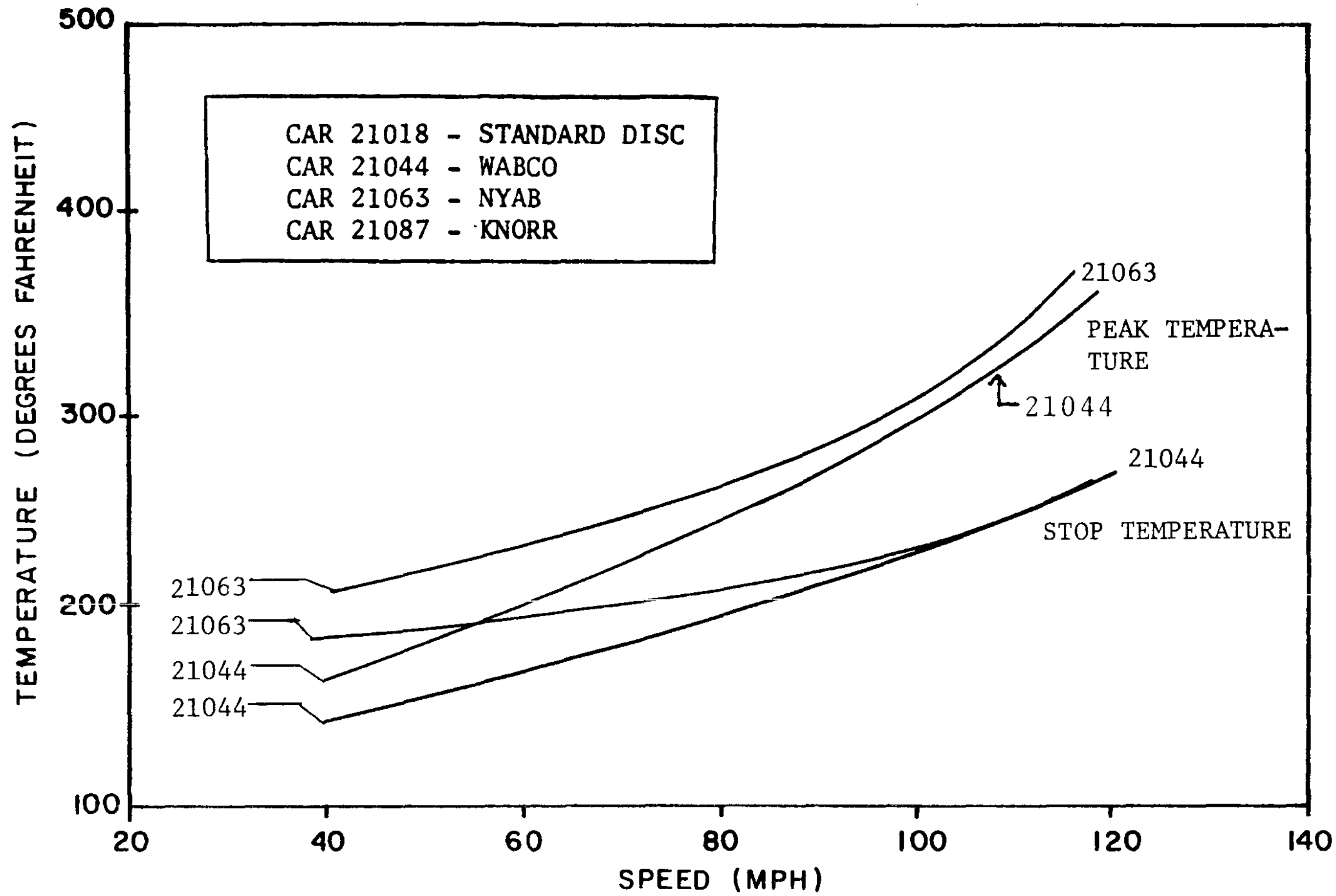

Figure 6-21. Summary of Results - Tread Temperature Measurements - Car Nos. 21044 and 21063 - Emergency Braking - 50/50 Disc/Tread Ratio

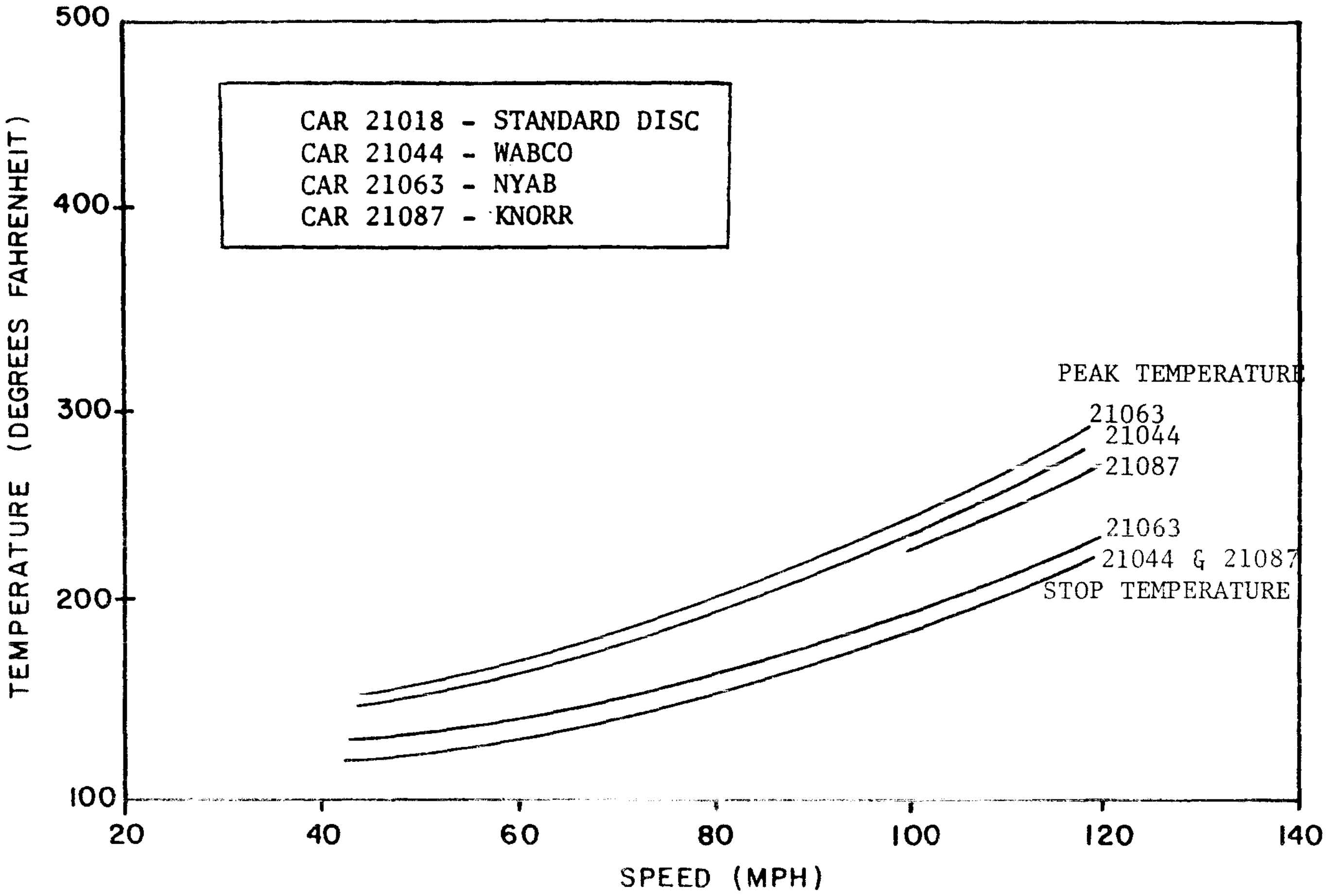

Figure 6-22. Summary of Results - Disc Temperature Measurements Car Nos. 21044, 21063 and 21087 - Full Service Braking 60/40 Disc/Tread Ratio

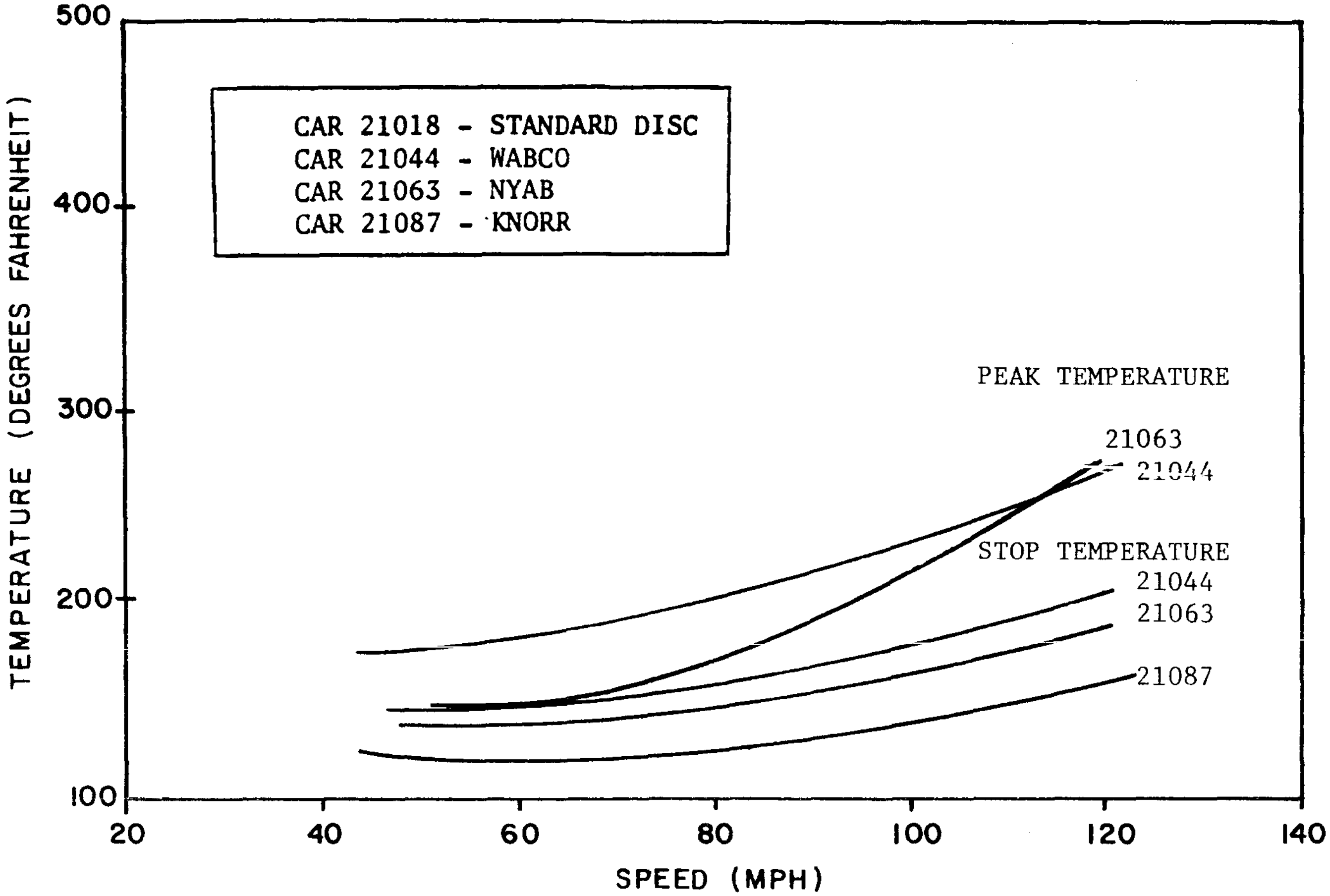

Figure 6-23. Summary of Results - Tread Temperature Measurements - Car Nos. 21044, 21063 and 21087 - Full Service Braking 60/40 Disc/Tread Ratio

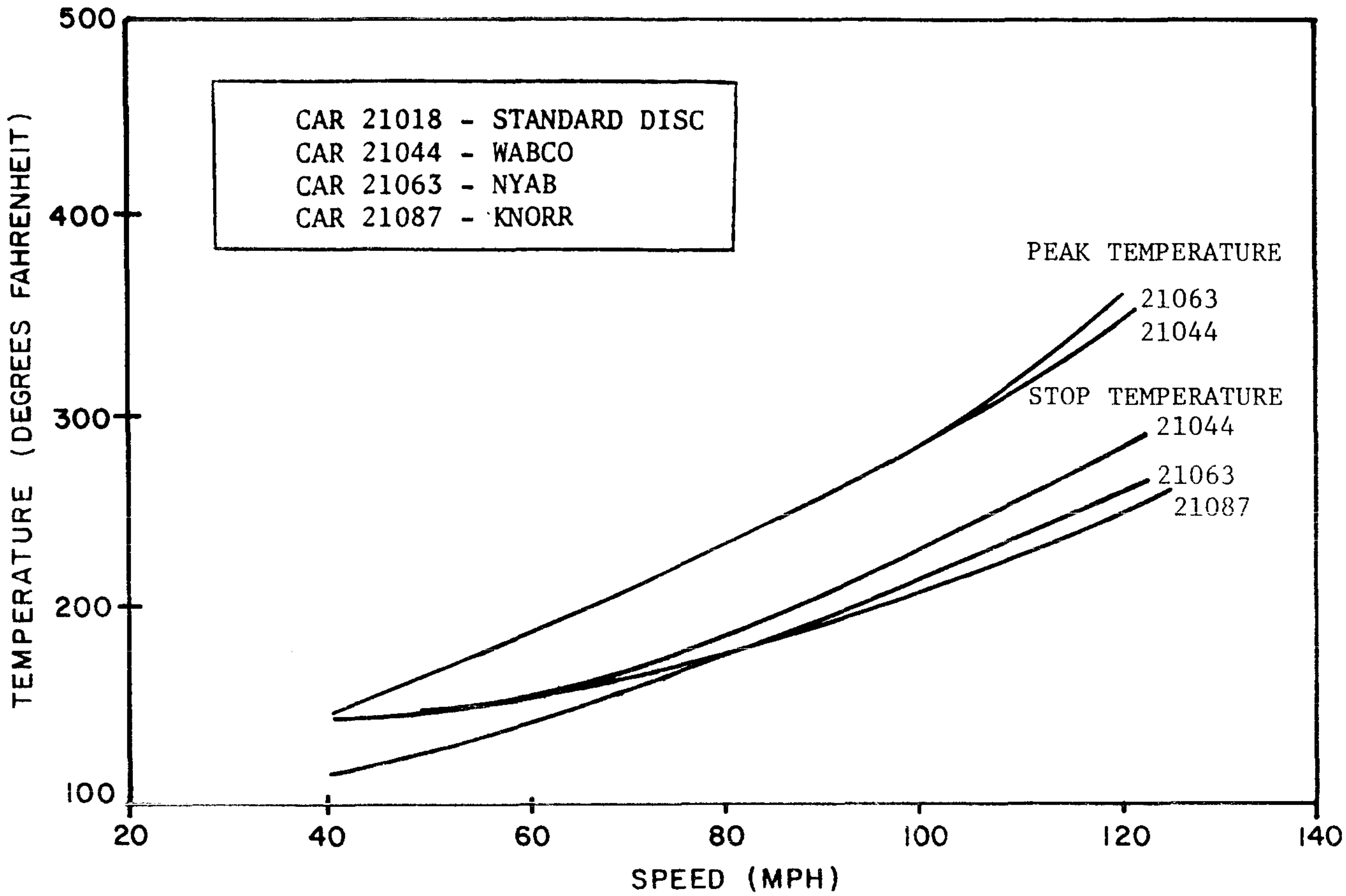

Figure 6-24. Summary of Results - Disc Temperature Measurements - Car Nos. 21044, 21063 and 21087 - Emergency Braking - 60/40 Disc/Tread Ratio

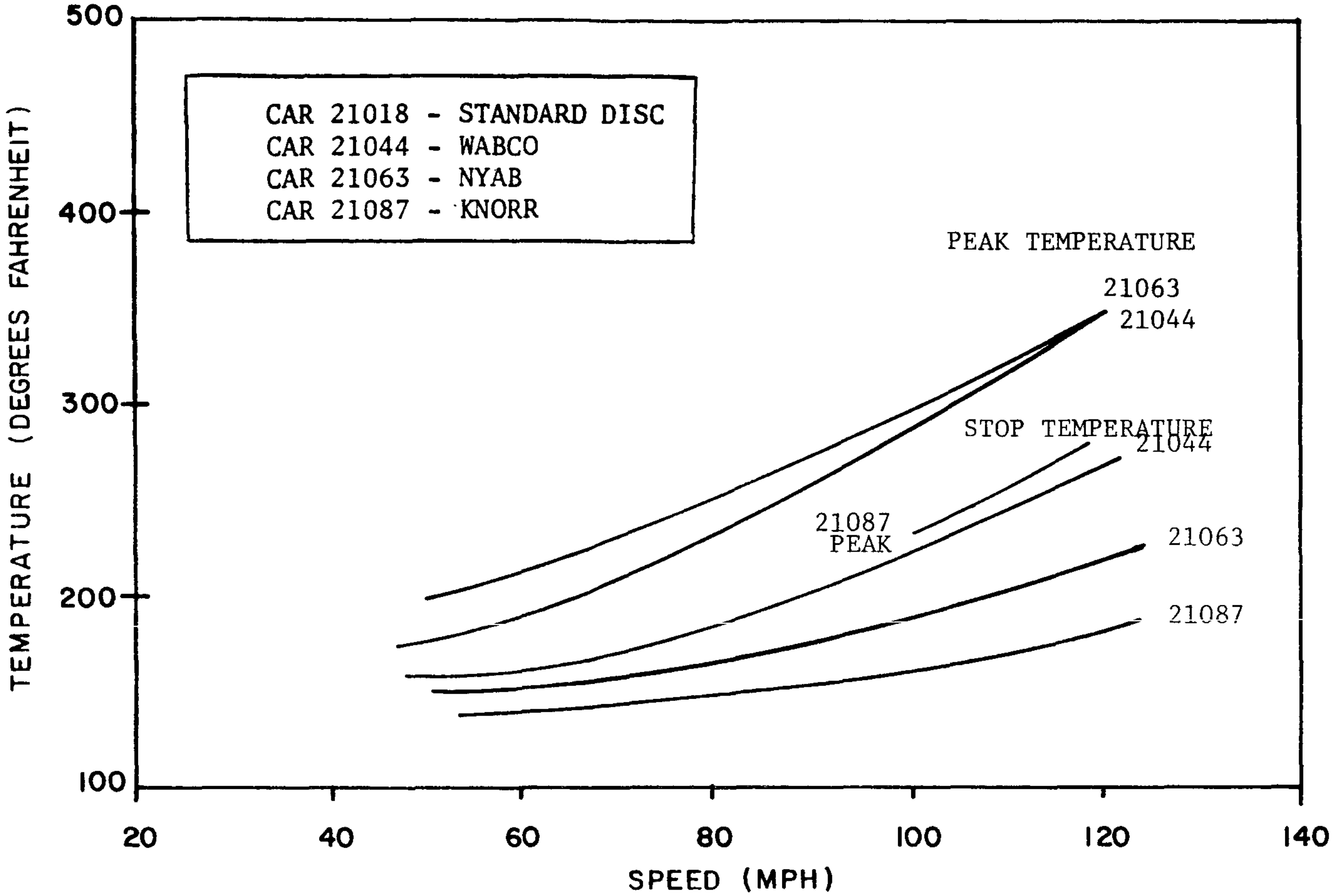

Figure 6-25. Summary of Results - Tread Temperature Measurements - Car Nos. 21044, 21063 and 21087 - Emergency Braking - 60/40 Disc/Tread Ratio

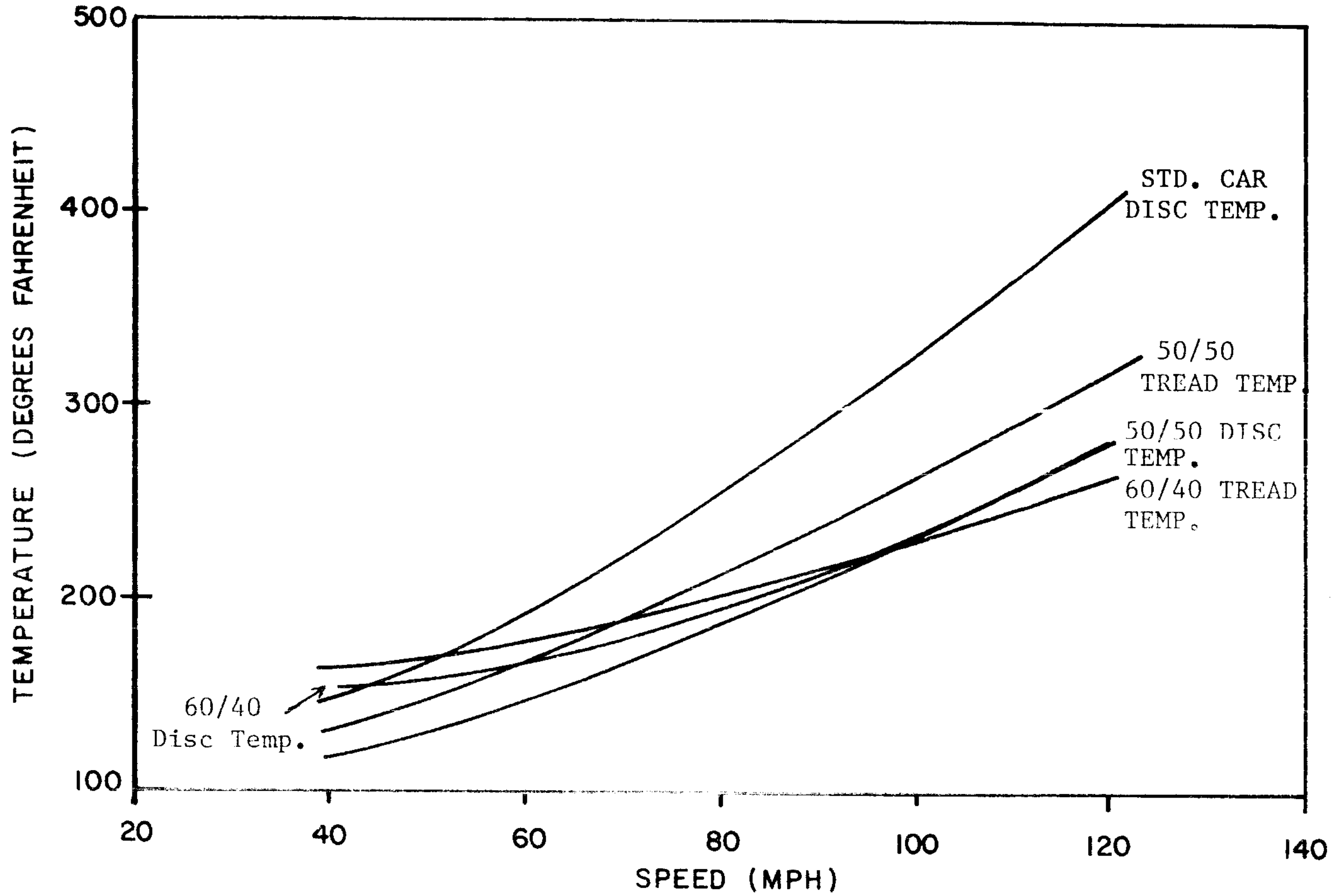

Figure 6-26. Summary of Results - Peak Temperature Measurements with Car Moving. Car No. 21044 - Full-Service Braking - WABCO Dual Brakes

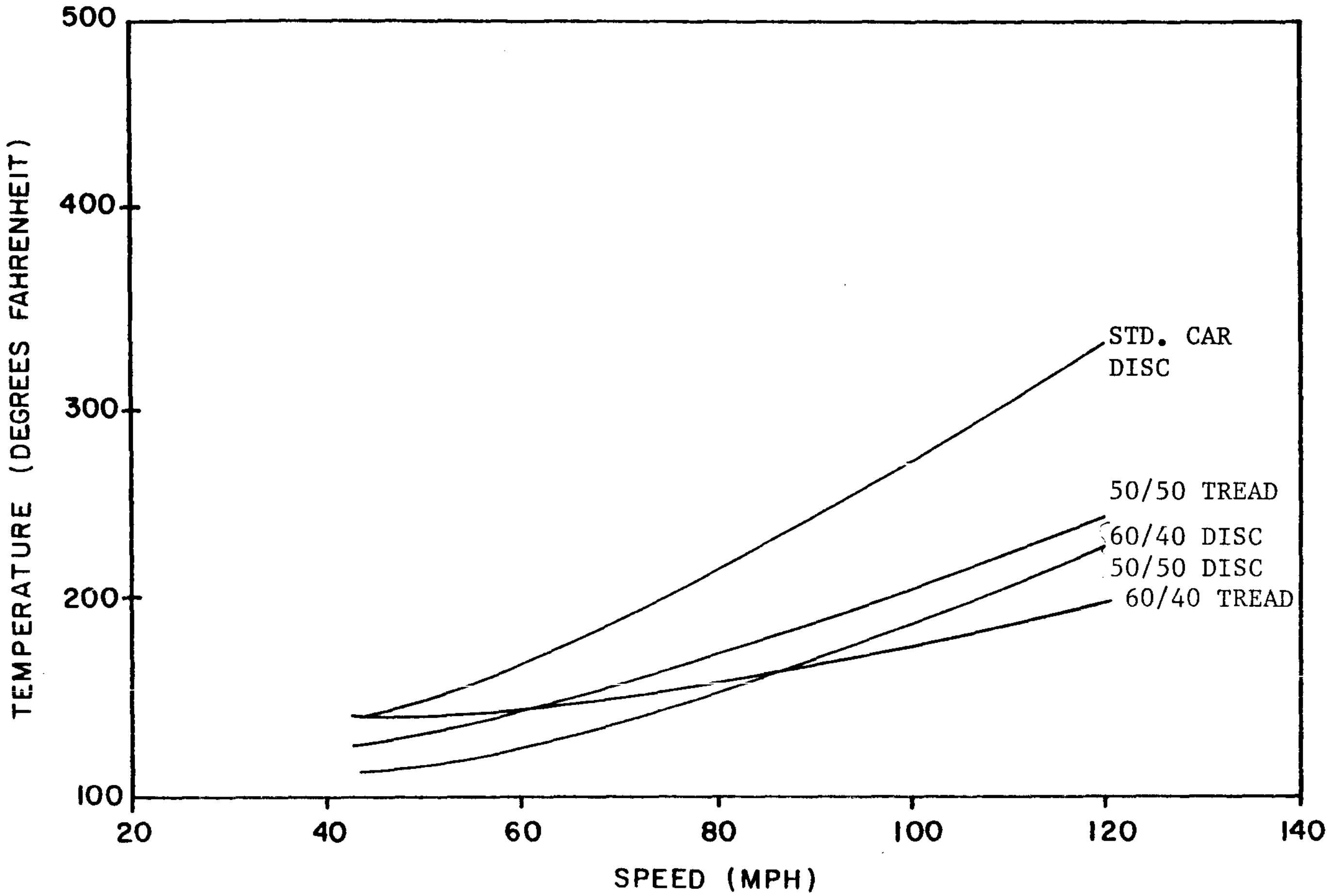

Figure 6-27. Summary of Results - Temperature Measurements After Car Stopped. Car No. 21044- Full - Service Braking - WABCO Dual Brakes

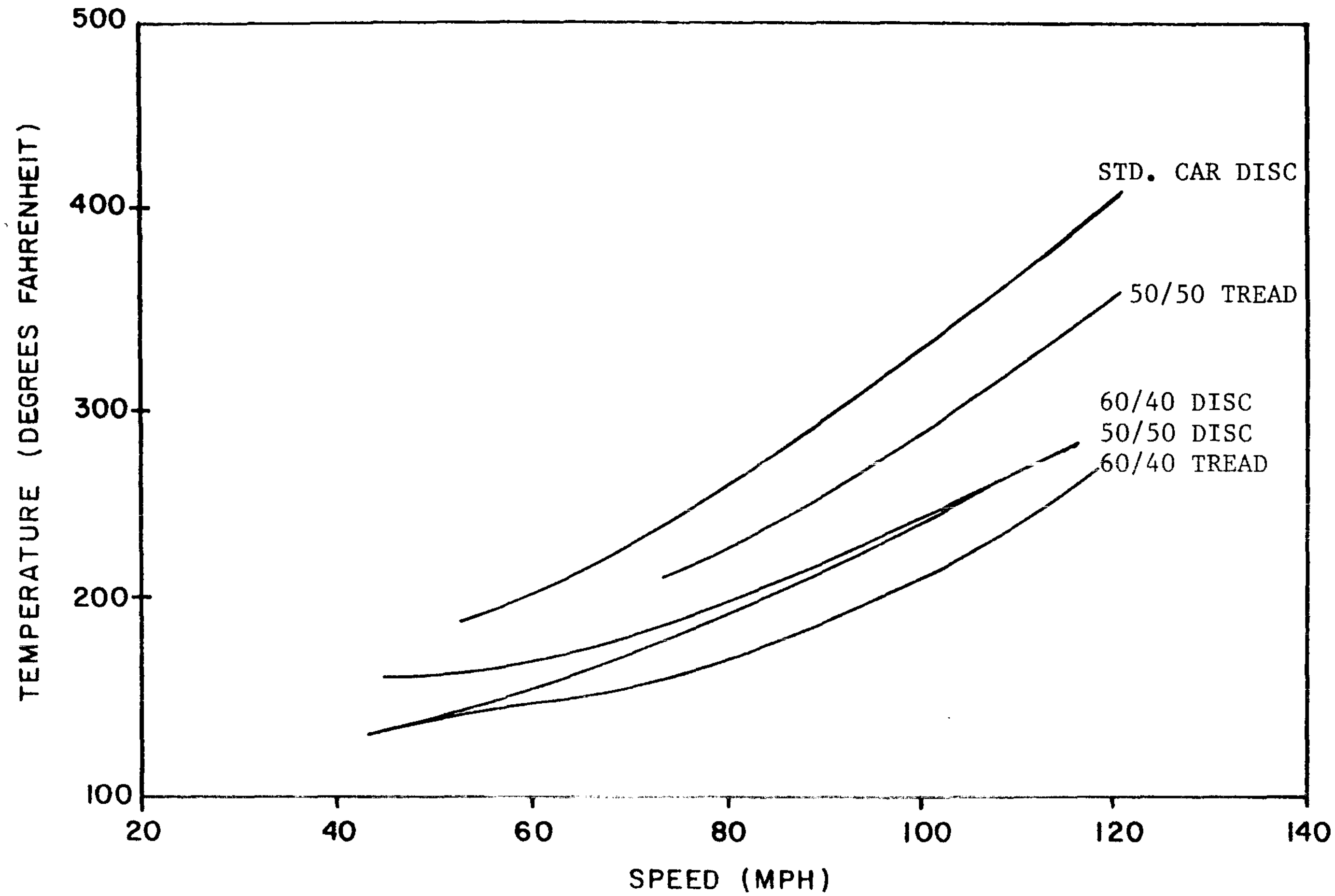

Figure 6-28. Summary of Results - Temperature Measurements With Car Moving - Car No. 21063 - Full Service Braking - NYAB Dual Brakes

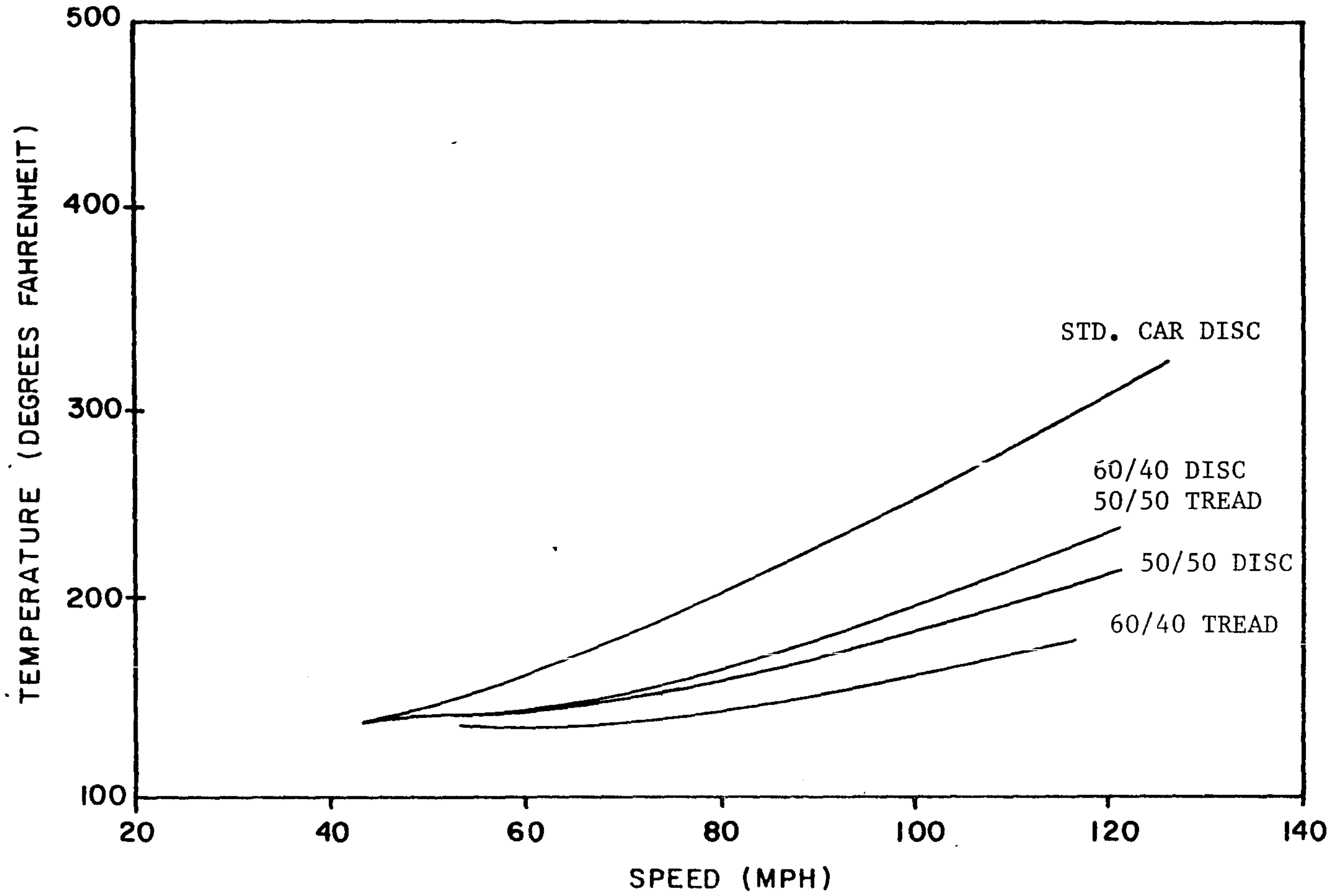

Figure 6-29. Summary of Results - Temperature Measurements After Car Stopped - Car No. 21063 - Full Service Braking - NYAB Dual Brakes

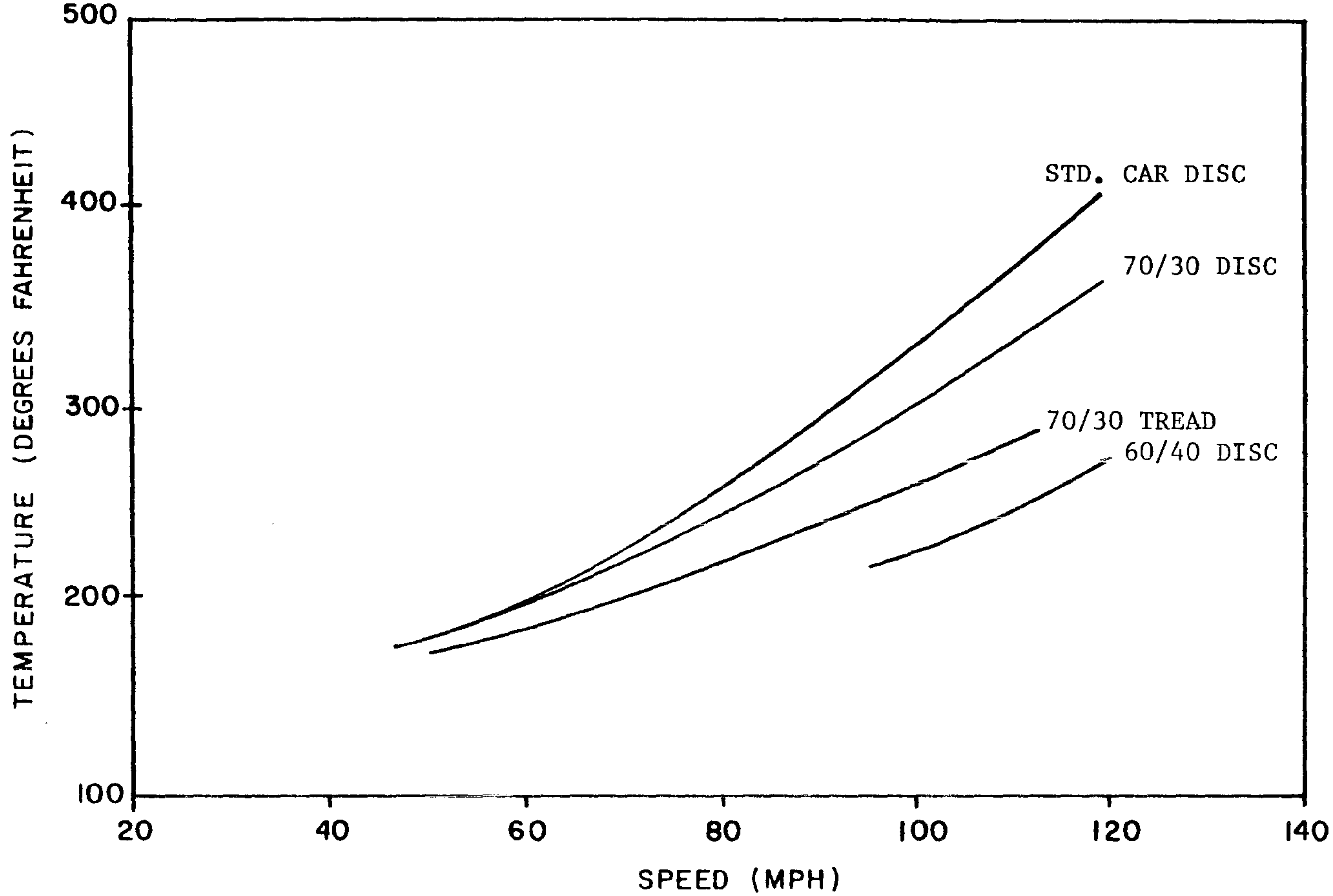

Figure 6-30. Summary of Results - Peak Temperature Measurements with Car Moving.- Car No. 21087 - Full-Service Braking - Knorr Dual Brakes

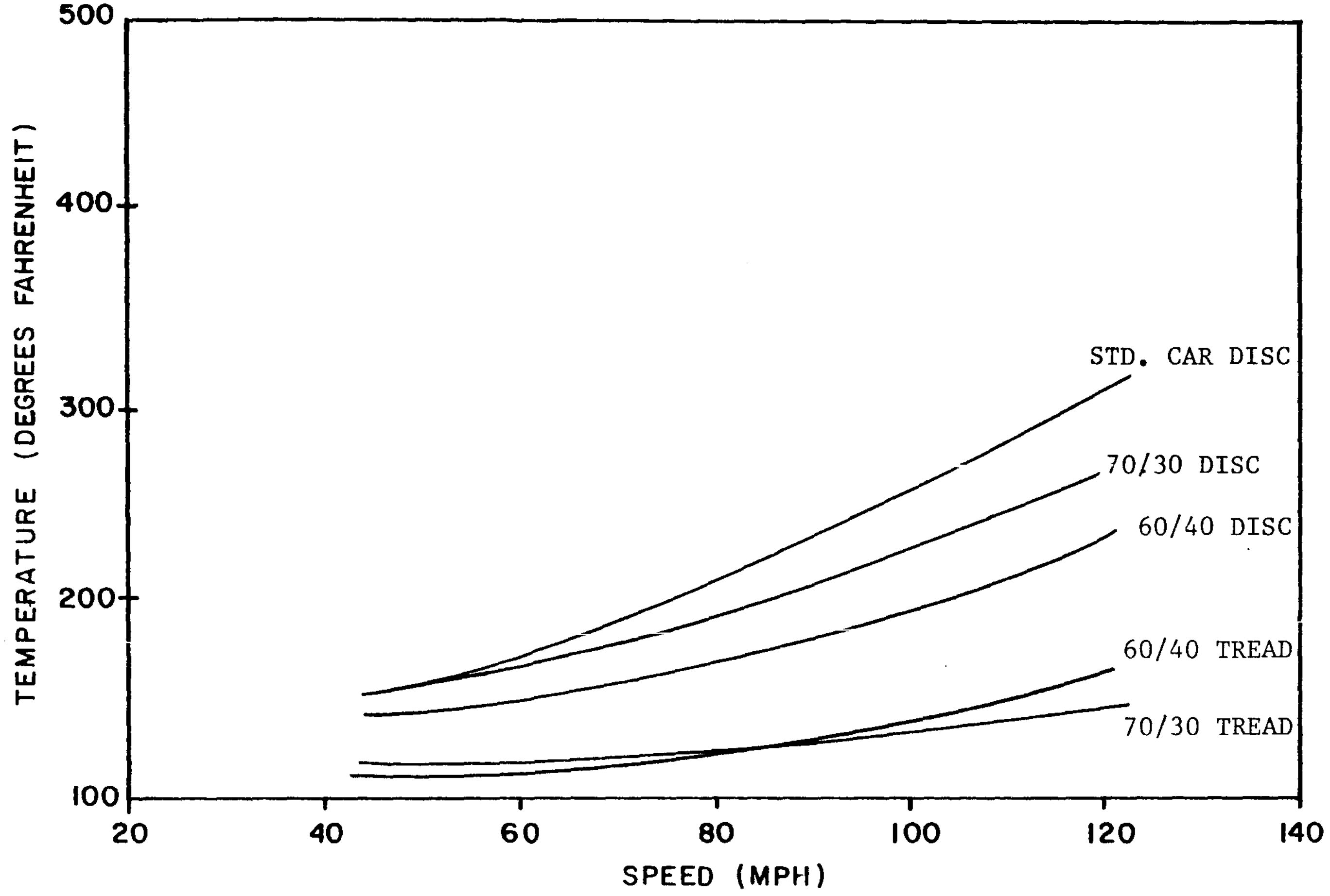

Figure 6-31. Summary of Results - Temperature Measurements After Car Stopped - Car No. 21087 - Full Service Braking - Knorr Dual Brakes

Except for a few cases, the data obtained from the optical pyrometers compare quite well with the data obtained from the hand-held pyrometers after the cars stopped. Both sets of data tend to agree better at higher speeds.

The dispersion in the infrared data taken with the optical pyrometers was probably caused by emissivity changes. The infrared sensors were adjusted to correct for the variations in emissivity but the adjustment technique probably requires further development to improve temperature measurements made on a moving car.

The results show that the difference between the temperatures measured when the car is moving with the brakes applied, and after the car is stopped increase as car speed increases. The increase in the difference is reasonable, since maximum kinetic energy is dissipated as the car is stopped from higher speeds and the tread-surfaces have a longer time to cool. The combined test results indicate that the maximum temperature difference for the disc-brake surfaces was about 80 degrees Fahrenheit while the maximum difference for the wheel-tread surfaces was about 100 degrees Fahrenheit.

The results from all tests run at the 50/50, disc/tread ratio on Car No. 21044 (developed by WABCO) and Car No. 21063 (developed by NYAB) indicate that the differences between disc and wheel-tread temperatures were very much the same. Car No. 21063 appeared to have higher peak temperatures for full-service braking. This difference is probably a measurement error, since the temperatures measured after the car stopped showed that the temperatures were identical. Based on the temperatures measured while the car was moving with brakes applied and while the car was stopped, it appears that the temperatures measured on Car No. 21063 should be adjusted downward to agree with the temperature curve for Car No. 21044.

The disc-brake temperature results for all cars operated at the 60/40, disc/tread ratio at full-service braking agree very well for the systems developed by the three brake manufacturers. The temperature results obtained for all cars operated at the 60/40, disc/tread ratio at emergency-service braking show good agreement for the three systems.

Figures 6-26 through 6-31 are summaries of the temperature results obtained from the dual-braked cars and the standard car (disc-brakes only). The standard car temperatures are shown on each graph to provide a common reference. It is evident that the disc temperatures were significantly lower on the cars equipped with dual-brakes as compared to the disc temperatures on the standard car. The temperature data also shows that the tread-temperatures were higher at the 50/50 disc/tread ratio than at the 60/40 ratio.

The test results show that disc temperatures were approximately 120 degrees lower for the dual-braked systems than for the standard system (disc only) for similar full-service applications.

Results obtained testing Car No. 21044 (equipped with the WABCO system) indicate that the disc temperatures (at 50/50 and 60/40 disc/tread ratios) were approximately the same. However, the tread temperatures were significantly lower at the 60/40 disc/tread ratio. Therefore, the 60/40 disc/tread ratio appears to provide a better division of the braking effort between the disc and tread systems.

Results obtained testing Car No. 21063 (equipped with the NYAB system) were very similar to those obtained with the WABCO system. The disc temperatures were about 120 degrees lower than those measured on the standard car for the 120-mph test. However, the tread temperatures measured at the 50/50 disc/tread ratio were much higher than those measured at the 60/40 ratio. The results seem to indicate that the 60/40 ratio is much superior to the 50/50 ratio for this system. Also, at the 60/40 ratio, the maximum disc temperatures were 120 degrees less than the peak disc temperatures measured on the standard car while the peak tread temperatures were substantially reduced.

The Knorr-equipped car was the only car tested at the 70/30 ratio. The peak-temperature data show the tread temperatures at the 70/30 ratio to be higher than the disc temperatures at the 60/40 ratio. However, the data taken after the car stopped show a more logical pattern in the relative measurements. Therefore, the data taken after the car stopped is believed to be better data. In this case the 60/40 disc/tread data might be preferred, depending on the desired disc/tread temperature objectives. At 120-mph, the disc temperatures were about 100 degrees lower than those measured on the standard car for the 60/40 ratio and only 50 degrees lower for the 70/30 ratio.

The tread temperatures were much lower than the disc temperatures in both cases. The tread temperatures at the 60/40 ratio were nearly the same as those measured at the 70/30 ratio. This result appears to be a particular characteristic of the Knorr/Bremse system, since the other temperature results do not suggest that the tread temperatures will remain this low as the demand on the disc system is reduced.

6.5 WHEEL TREAD CONDITION

As part of the dual-brake test, wheel condition was monitored on all cars. The wheel inspections indicated that there was a definite improvement in wheel-tread condition. In the process of moving the test cars to Transportation Test Center, the wheels on the test cars were damaged to varying degrees while being towed in freight consist. The wheels on the reference coach and the other cars were turned to remove the defects, except where the defects were minor. As the tests were run, wheel condition was monitored. A definite improvement in wheel-surface condition was observed on the cars equipped with dual brakes; this improvement did not occur on the standard car equipped with the disc brakes only. The defects present at the start of the single-car cutaway tests were significantly reduced at the end of this test, and were almost eliminated at the end of the 10,233-mile simulation test. The test results clearly show that the tread brakes tend to smooth-out defects and to prevent the accumulation of new defects.

6.6 DECELERATION RATES FOR DUAL-BRAKED CARS

The instantaneous deceleration rates (calculated from the data collected on the single-car stop distance tests) are shown in Figures 6-32 to 6-38. To illustrate the typical results obtained from an Amcoach equipped with dual brakes, the deceleration vs. speed curves for the 60/40 disc/tread ratio are combined in Figures 6-39 and 6-40 for full-service and emergency-service braking.

In addition, the full-service deceleration data from the standard Amcoach equipped with disc brakes only (with brake-cylinder pressure at 68 psi) is shown in the combination retardation curves (Figures 6-32 through 6-38). These curves show that the adhesion demands are significantly lower (at speeds below 45 mph) for cars equipped with dual brakes. Car No. 21044 (equipped with the WABCO dual-brake system at 60/40 disc/tread ratio) decelerated faster than the standard car at speeds above 45 mph. This probably occurred because of the way the braking effort is developed in a dual-brake system. However the reduction in adhesion demand that corresponds to the reduction in retardation rate would help to reduce wheel sliding, and would provide an additional benefit for using a dual-brake system.

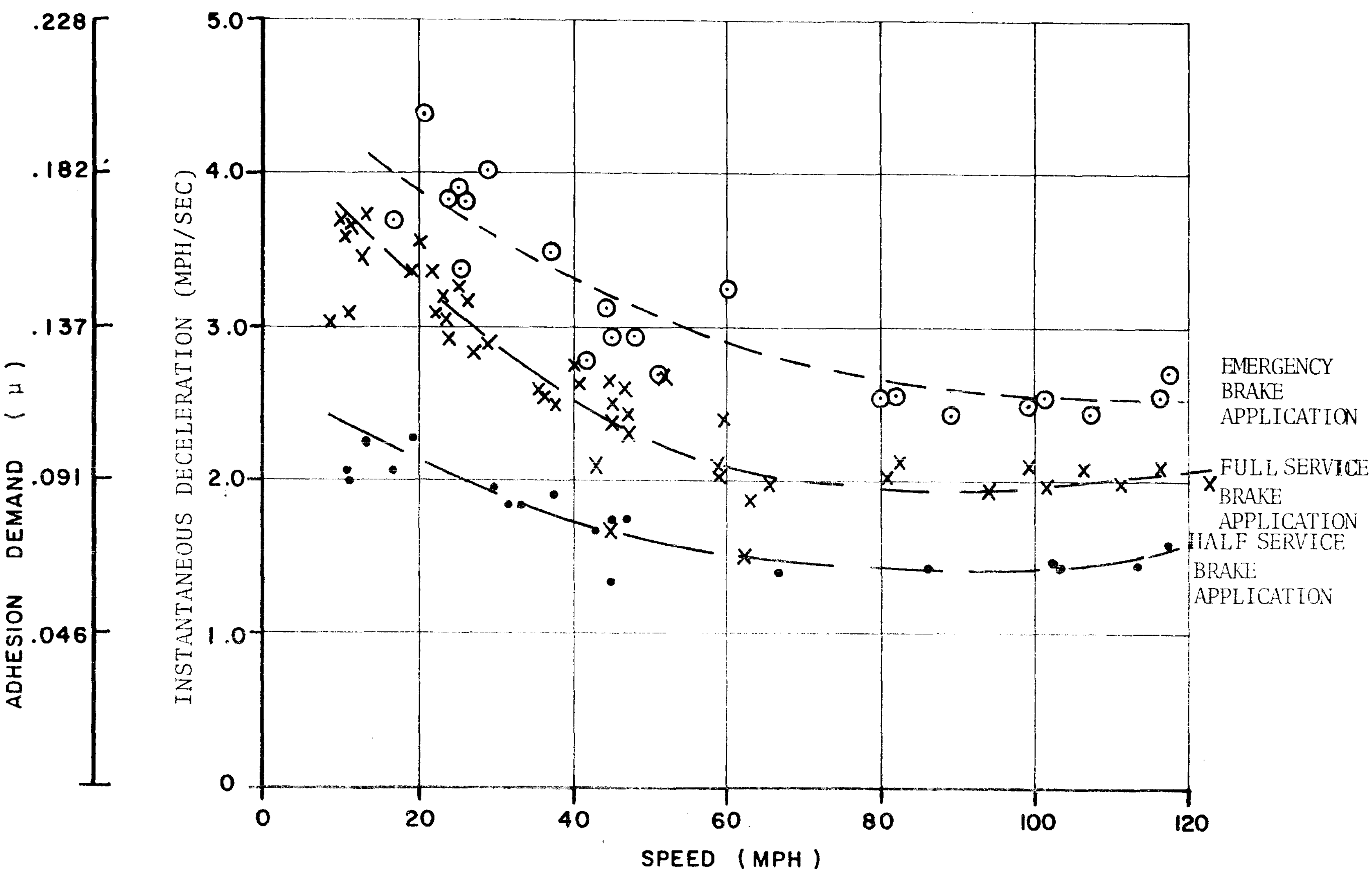

Figure 6-32. Velocity vs. Deceleration for Braking Standard Car (No. 21018)

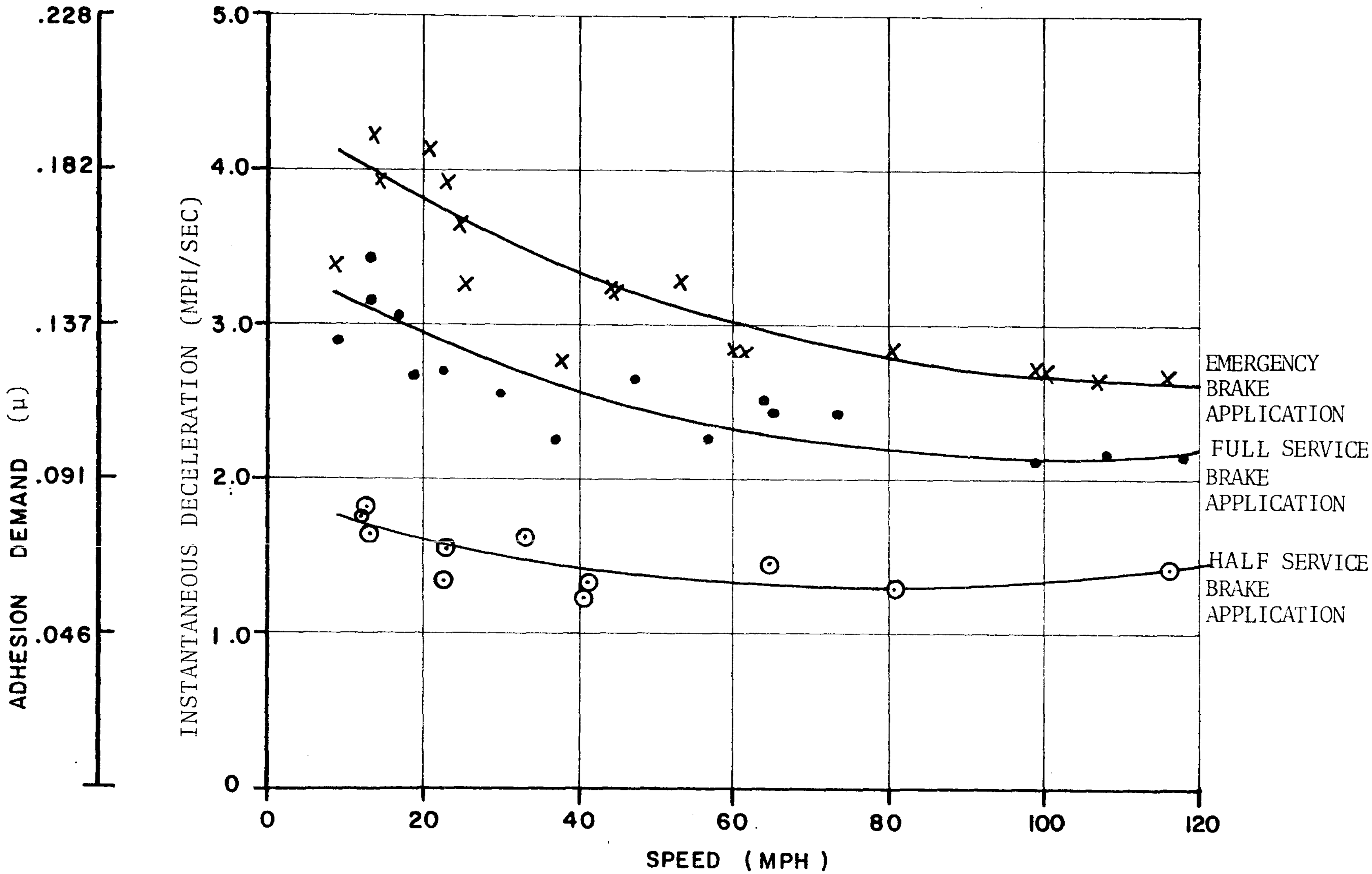

Figure 6-33. Velocity vs. Deceleration for WABCO Dual-Braked Car (No. 21044) 50/50 Disc/Tread Ratio

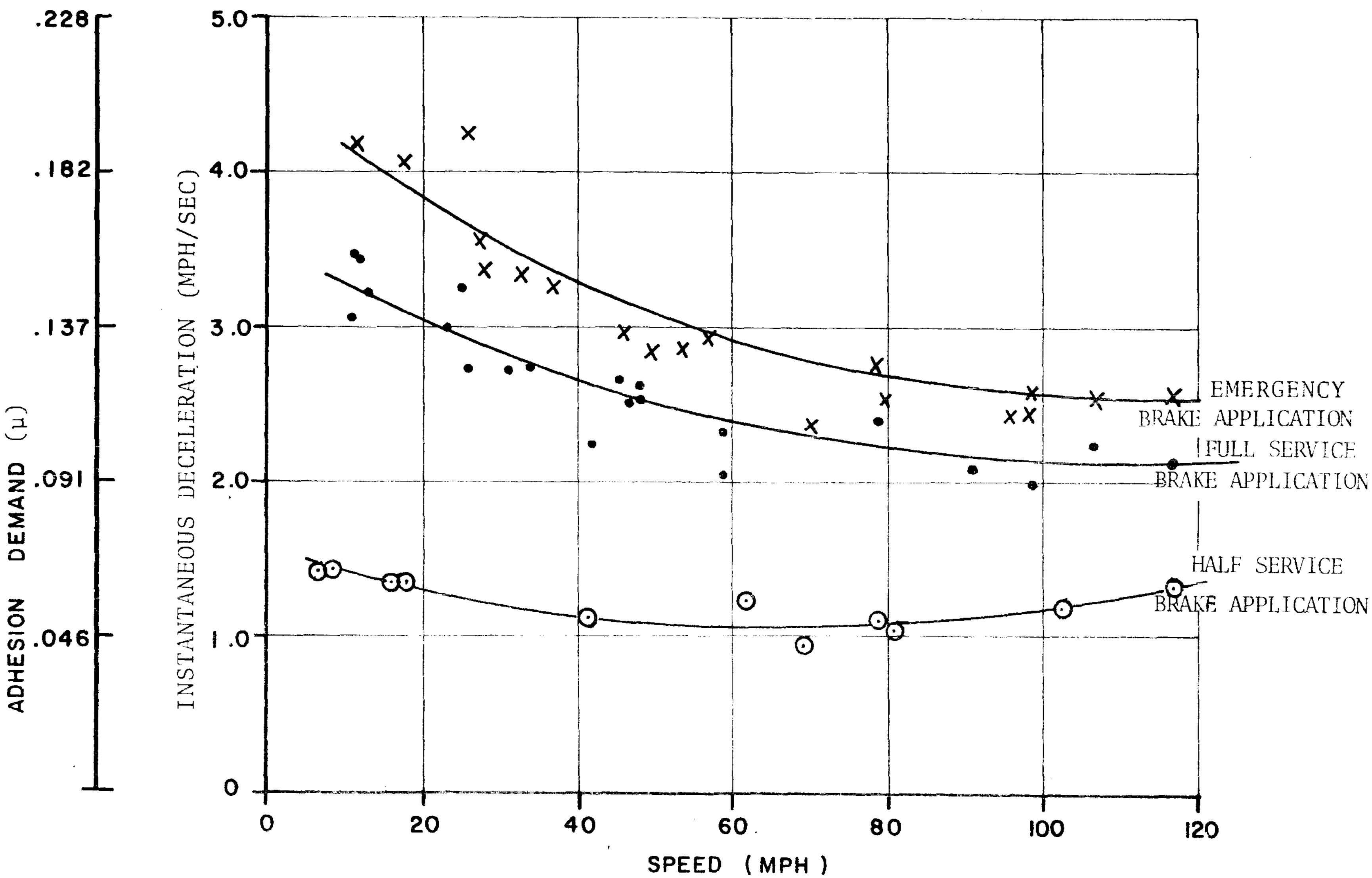

Figure 6-34. Velocity vs. Deceleration for WABCO Dual-Braked Car (No. 21044) 60/40 Disc/Tread Ratio

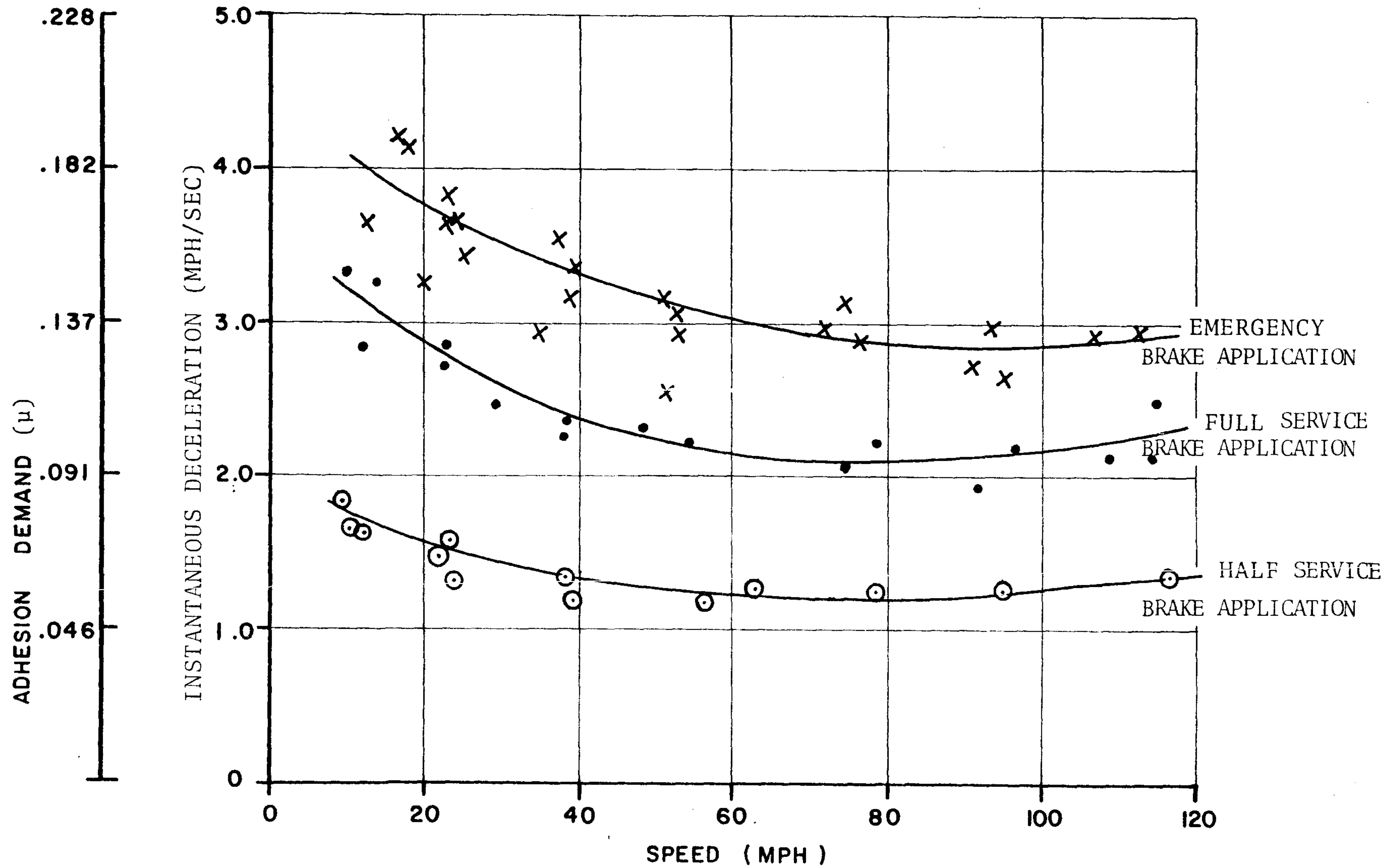

Figure 6-35. Velocity vs. Deceleration for NYAB Dual-Braked Car (No. 21063) 50/50 Disc/Tread Ratio

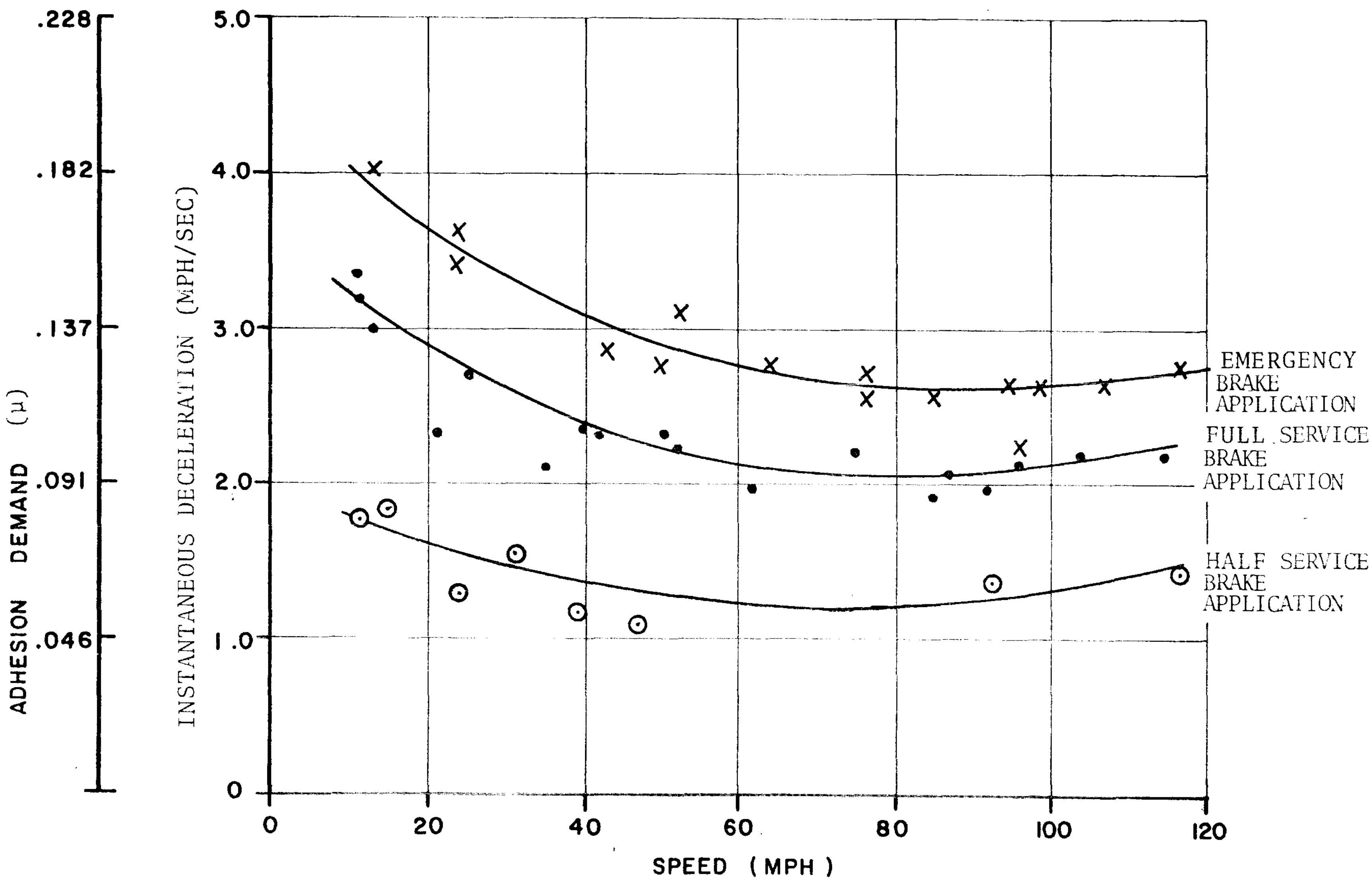

Figure 6-36. Velocity vs. Deceleration for NYAB Dual-Braked Car (No. 21063) 60/40 Disc/Tread Ratio

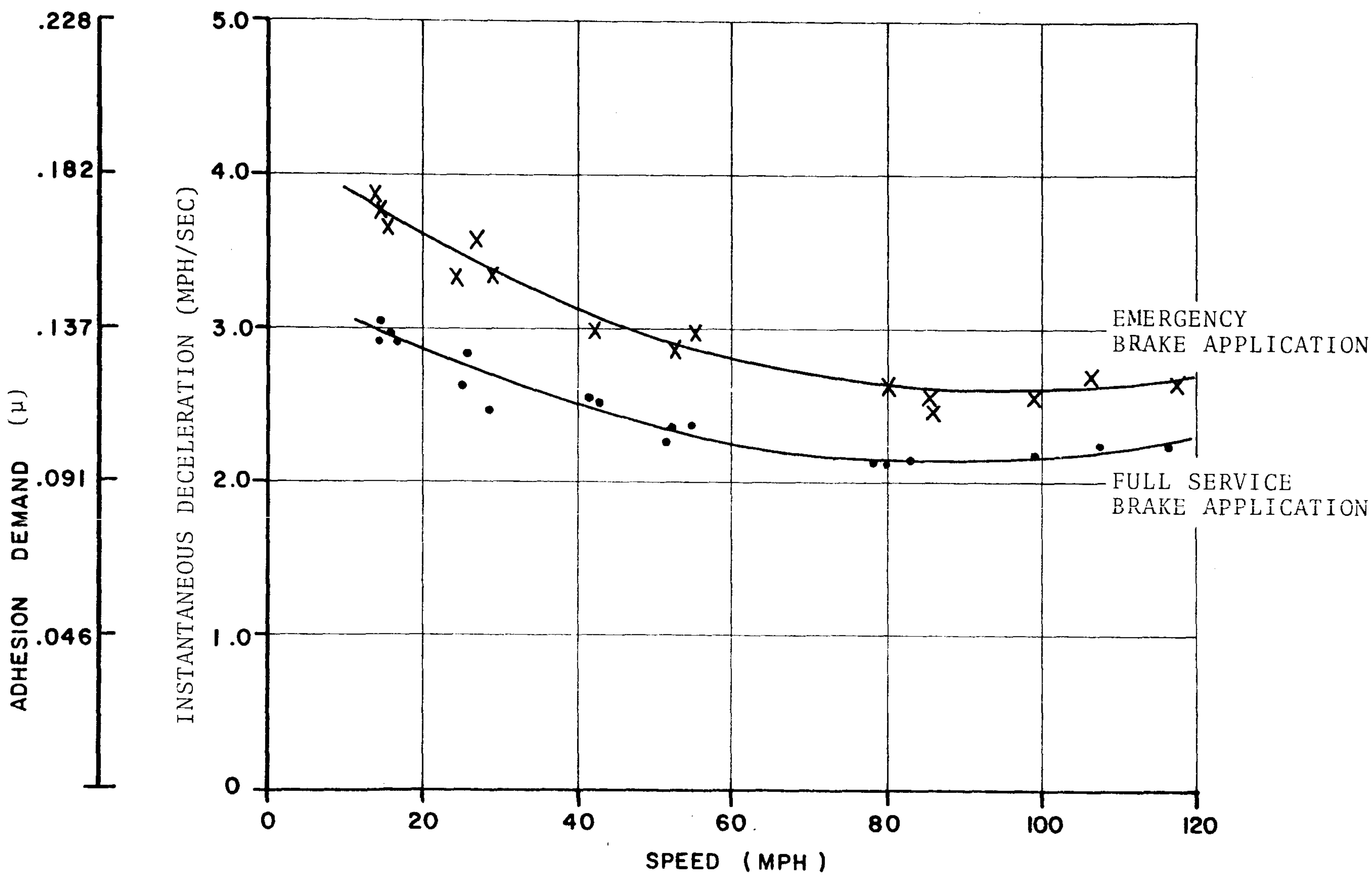

Figure 6-37. Velocity vs. Deceleration for Knorr Dual-Braked Car (No. 21087) 60/40 Disc/Tread Ratio

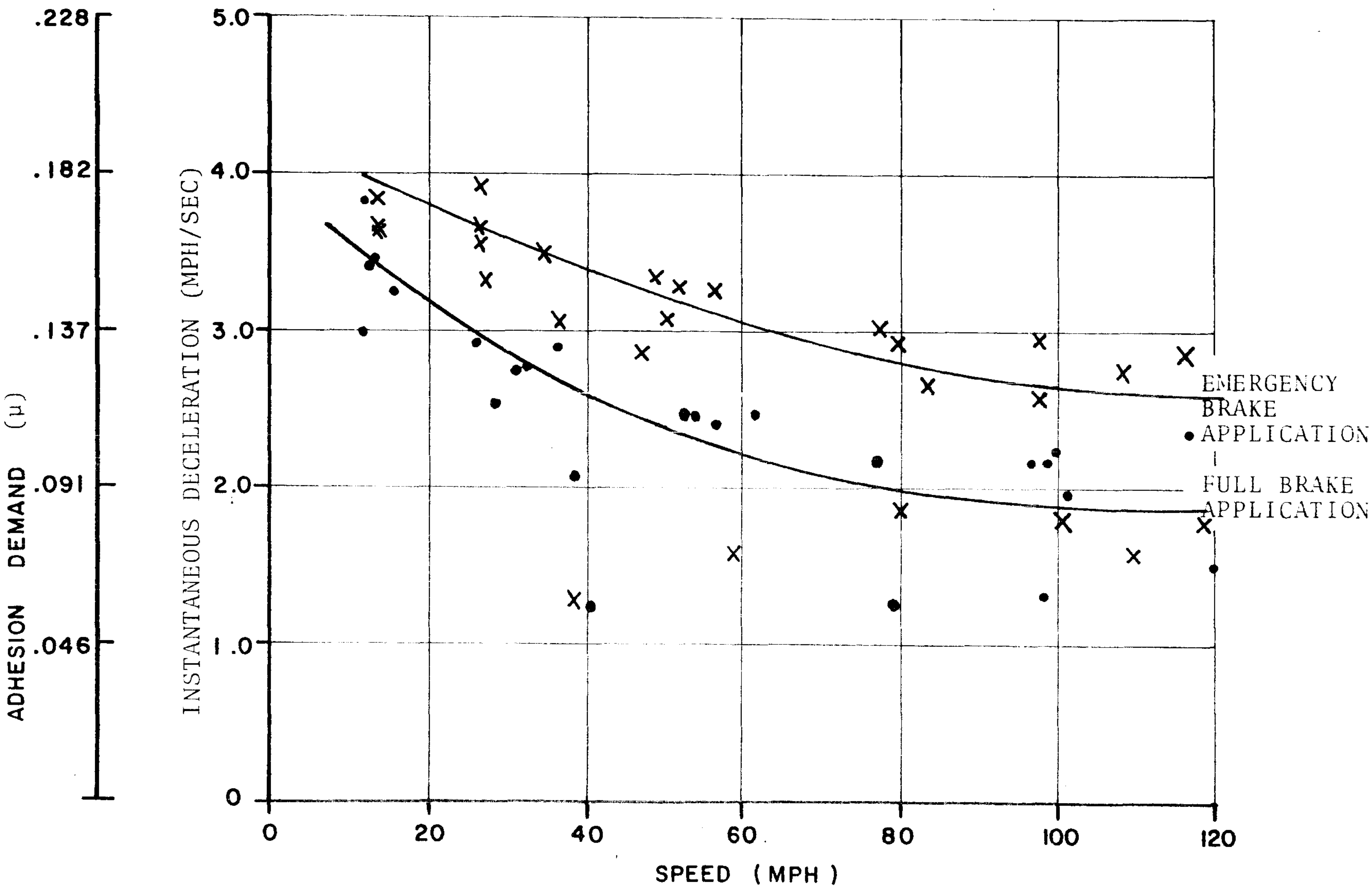

Figure 6-38. Velocity vs. Deceleration for Knorr Dual-Braked Car (No. 21087) 70/30 Disc/Tread Ratio

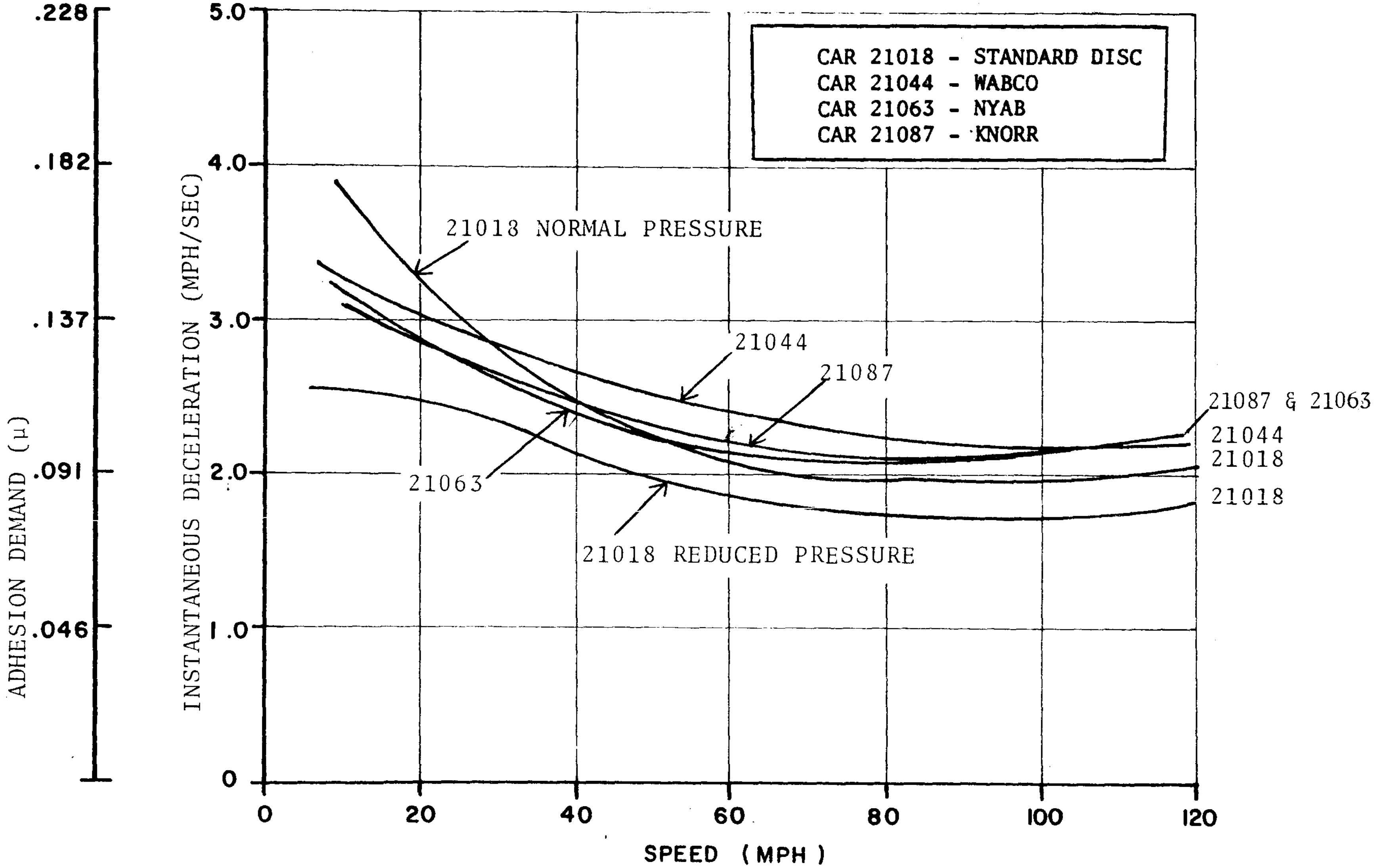

Figure 6-39. Deceleration vs. Speed Curves for Dual-Braked Cars - Full Service Braking - 60/40 Disc/Tread Ratio

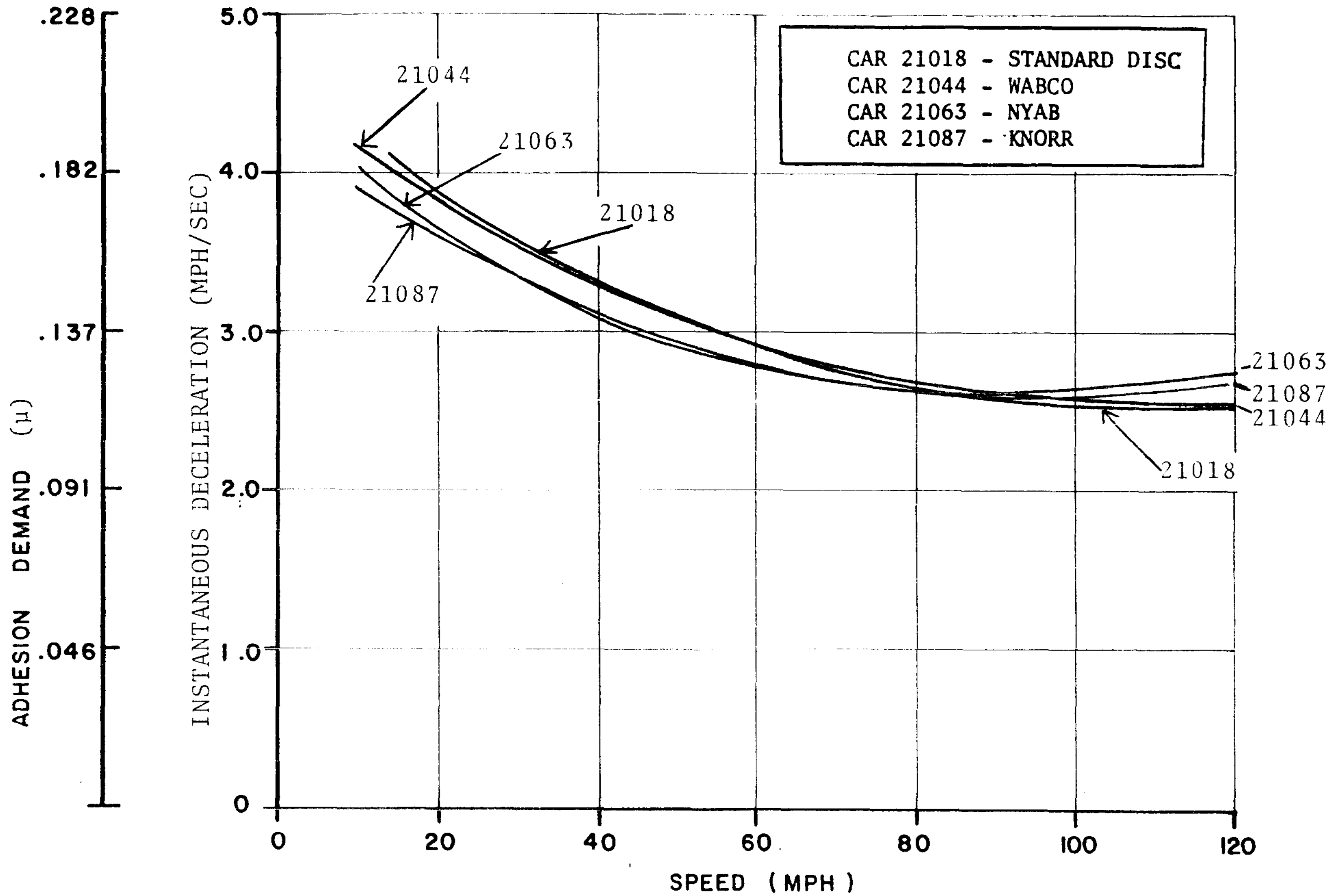

Figure 6-40. Deceleration vs. Speed Curves for Dual-Braked Cars - Emergency Service Braking - 60/40 Disc/Tread Ratio

The deceleration data which is an indication of adhesion demand is compared to available adhesion data in Figures 6-39 and 6-40. The results from the single-car, stop-distance tests at the 60/40 disc/tread ratio were selected for this comparison, since the temperature results seem to indicate that the 60/40 disc/tread ratio may be the preferred selection.

Figure 6-41 shows the deceleration rate of the standard Amcoach and the dual disc/tread brakes with the braking requirements for Amcoaches as defined in the car specification. This figure shows that the dual brakes match the desired adhesion-demand curves much better than the existing disc-only system.

6.7 NORTHEAST CORRIDOR SIMULATION

The Northeast Corridor Simulation Test showed that each of the candidate dual-brake systems had an observable effect on wheel-tread condition. Defects in the tread surface, which were present at the start of the test, were significantly reduced while the test was being run. No significant difference in wheel wear was observed during the 10,233-mile test. The other result of the simulation test is shown in Tables 6-1 and 6-2.

Part of the purpose of the simulation was to test the candidate brake systems under severe operating conditions to observe the performance of the brake systems at higher temperatures. In actual service, Amcoach brakes are subjected to severe heating because of repeated stops by accepted but not approved operating procedures. High demands are placed on the heat dissipation capabilities of the brake system by bailing-off and power braking operations. Some locomotive engineers save the locomotive wheels by allowing the Amcoaches to do all the braking and, at times, the consist is towed with the coach brakes applied.

These operational practices were incorporated into the Northeast Corridor Simulation Test to check maximum operating temperatures at adverse operating conditions. The optical pyrometers were not installed for the simulation tests; therefore, temperature data was taken after the car stopped.

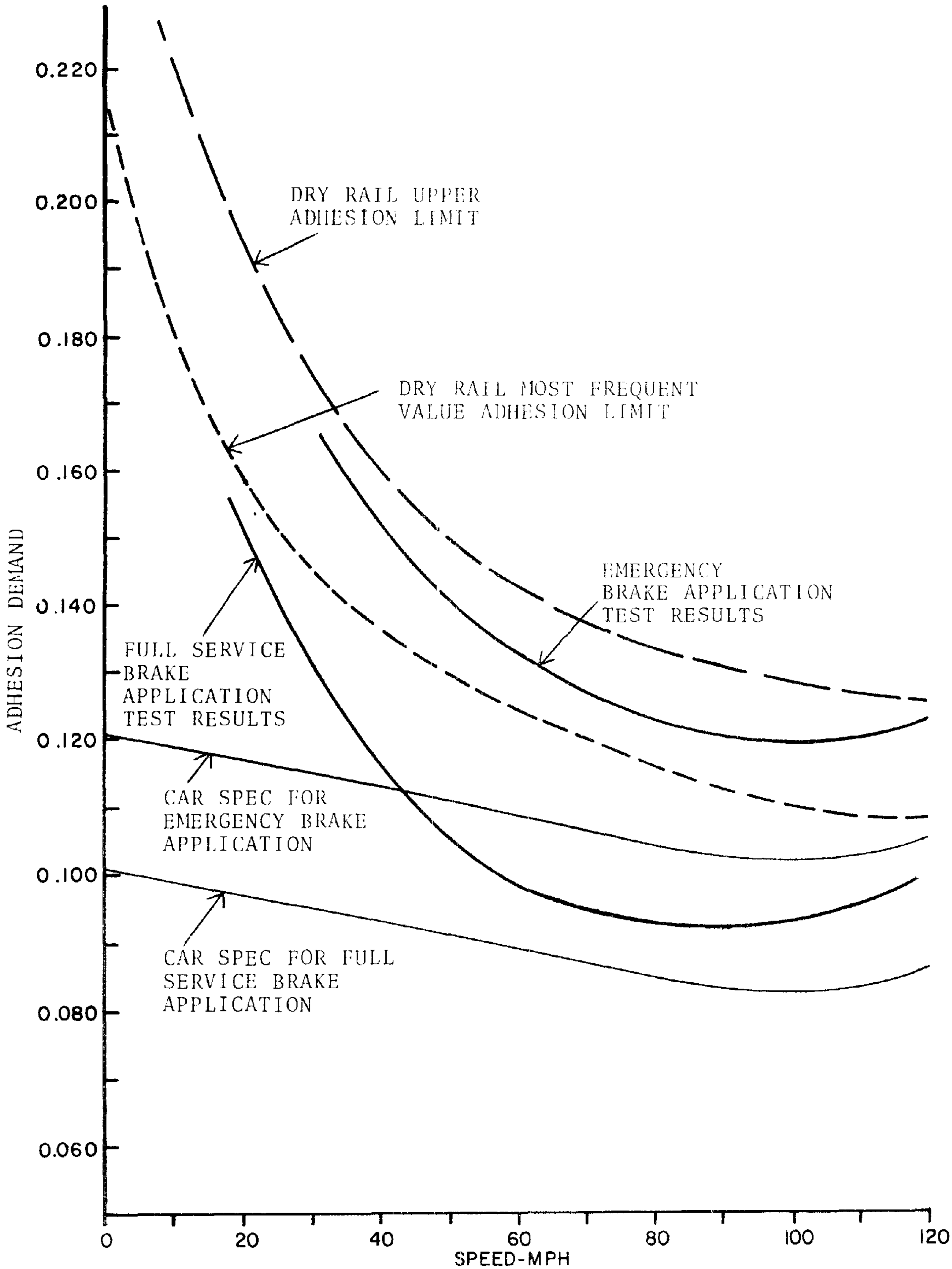

Figure 6-41. Deceleration Rate of Standard Amcoach and Dual-Braked Amcoaches Compared to Amcoach Specification

TABLE 6-1

NEC SIMULATION TEMPERATURES

ORIGINAL PROFILE

Station	Car 21018 Temperature Range (Degrees Fahrenheit)
Trenton, NJ	275 - 260
Philadelphia, PA	330 - 275
Wilmington, DE	310 - 275
Baltimore, MD	285 - 240
Beltway, MD	255 - 240
Washington, DC	365 - 295

MODIFIED PROFILE

Station	Car No. 21018 Temperature Range (Degrees Fahrenheit)	Car No. 21044 Temperature Range (Degrees Fahrenheit)	
		Disc	Tread
Trenton, NJ	370 - 260	215 -185	145 -110
Philadelphia, PA	240 - 200	150 -130	135 -120
Wilmington, DE	285 - 255	175 -160	140 -120
Baltimore, MD	390 - 320	255 -185	170 -130
Beltway, MD	415 - 335	230 -196	155 -120
Washington, DC	375 - 305	230 -180	160 -120

MODIFIED PROFILE WITH POWER BRAKING

Station	Car No. 21018 Temperature Range (Degrees Fahrenheit)	Car No. 21044 Temperature Range (Degrees Fahrenheit)	
		Disc	Tread
Philadelphia, PA	370 - 325	230 -195	165 -140
Wilmington, DE	320 - 260	170 -145	145 -130
Baltimore, MD	380 - 290	215 -180	160 -140
Beltway, MD	460 - 390	280 -230	170 -145
Washington, DC	275 - 230	165 -135	155 -120

The temperature data taken on the NEC simulation shows that maximum temperature data taken after the car stopped was 415 degrees Fahrenheit for the standard car (disc-brakes only). The maximum temperatures measured on the dual-brake systems was 230 degrees Fahrenheit for the same stop. Assuming that after-stop temperatures are related to peak temperatures, the peak-temperature projections for the NEC operation are listed in Table 6-2.

When the NEC profile was modified to include power braking, the after-stop disc temperatures for the standard car reached 460 degrees Fahrenheit. The maximum disc temperature for the dual-braked car was 280 degrees Fahrenheit. The after-stop tread temperatures did not exceed 170 degrees Fahrenheit for the modified or the power-braking profile. By extrapolation from the single-car test data, peak tread temperatures can be projected as listed in Table 6-2. These data were developed from the single-car test data shown in Figure 6-42.

The NEC simulation test showed that tread brakes tend to clean-up defects in the tread surfaces, and that the disc temperatures on the Amcoaches equipped with dual brakes were significantly lower than disc temperatures on disc only systems. The NEC simulation tests indicate that the 60/40 disc/tread ratio would divert enough heat from the disc to make a significant reduction in disc temperatures while maintining reasonable wheel temperatures.

6.8 CONCLUSIONS

Each of the dual-brake systems was capable of stopping an Amcoach from 120 mph at rates similar to those used on standard Amcoaches in revenue service. The full-service brake application at 68-psi brake-cylinder-pressure resulted in a stopping distance of less than 5000 feet from a speed of 120 mph. The retardation rate varied from approximately 2.0 mph/second at 120 mph to 4.0 mph/second at speeds below 20 mph. The standard Amcoach stopped

TABLE 6-2

NEC SIMULATION TEST TEMPERATURE RESULTS

NOTE: ALL TEMPERATURES ARE IN DEGREES FAHRENHEIT

LOCATION	MODIFIED BRAKING PROFILE								
	STANDARD CAR			DUAL-BRAKE CAR					
	DISC			DISC			TREAD		
	Maximum After-Stop Temperature	ΔT	Projected Maximum Temperature	Maximum After-Stop Temperature	ΔT	Projected Maximum Temperature	Maximum After-Stop Temperature	ΔT	Projected Maximum Temperature
Trenton, NJ	370	+130	500	215	50	265	145	+30	175
Philadelphia, PA	240	+ 60	300	150	30	180	135	+30	165
Wilmington, DE	285	80	365	175	40	215	140	+30	170
Baltimore, MD	390	140	530	255	70	325	170	40	210
Beltway, MD	415	160	575	230	60	290	155	55	220
Washington, DC	375	130	505	230	60	290	160	40	200
	POWER BRAKE PROFILE								
Philadelphia, PA	370	130	500	230	60	290	165	40	205
Wilmington, DE	320	100	420	170	40	210	145	30	145
Baltimore, MD	380	130	510	215	50	265	160	35	195
Beltway, MD	460	200	660	280	80	360	170	40	210
Washington, DC	275	85	360	165	40	205	155	35	190

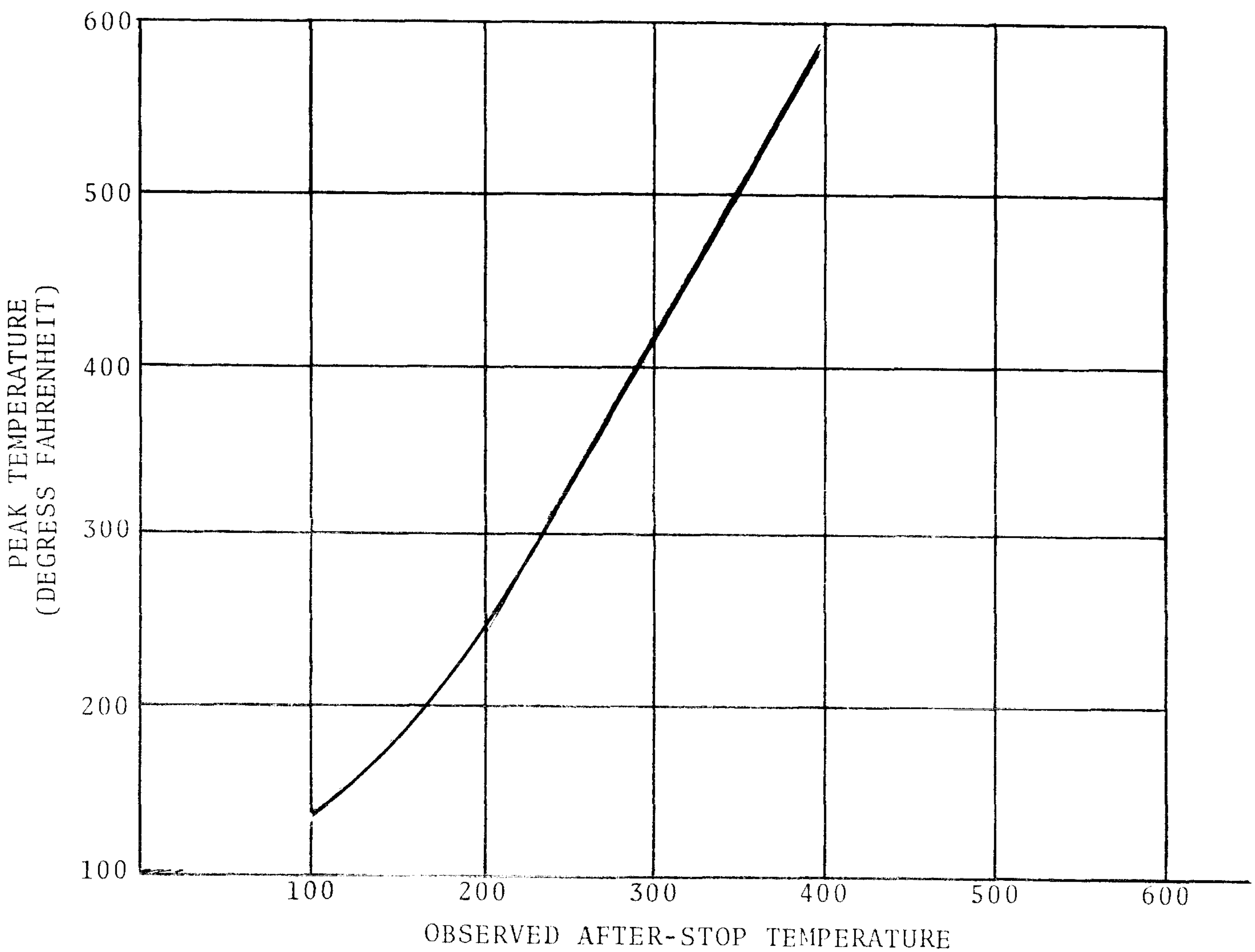

Figure 6-42. Peak Temperature vs. After-Stop Temperatures

from 120 mph in under 55 seconds. Therefore, the overall deceleration was 2.2 mph/second. The braking rate of standard Amcoaches appears to be too high at lower speeds in relation to specification requirements.

The brake manufacturers were asked to make the dual-brake systems match the braking rate of a standard Amcoach. The test results show that all cars were adjusted fairly well to match the standard-car braking rate for full-service braking. Also, the emergency rates were matched fairly well, but the half-service rates were not matched quite as well. Since half-service braking is not as severe, the need to have all cars share the braking equally is not as great. Therefore, the variation in brake rates at half-service braking is probably not a serious problem.

Some problems were encountered with the installation and operation of the dual-brake systems. However, all of the systems functioned well and after minor modifications all three systems have been placed in revenue service by Amtrak for further evaluation testing.

The temperature measurements show that the addition of the tread-brake system to the basic disc-only system on standard Amcoaches would add thermal capacity to the brake system and therefore reduce the disc temperatures. The results from the 120-mph tests made at 50/50 disc/tread ratio indicate that the peak disc temperatures were reduced to 120 degrees Fahrenheit. The results show that the 60/40 disc/tread ratio was better than a 50/50 ratio and was also slightly better than a 70/30 ratio.

Tread temperatures were greater than disc temperatures when the 50/50 disc/tread ratio was used. Tread temperatures were less than disc temperatures when the 60/40 disc/tread ratio was used. At this ratio, disc temperatures were approximately 180 degrees Fahrenheit less than those recorded for the disc-only system.

Peak temperatures measured during a stop were approximately 150 degrees Fahrenheit greater than the temperatures measured after the car stopped. The maximum running temperature measurements made on the treads were slightly higher than after-stop tread temperature measurements.

The test results show that the deceleration rate for cars equipped with dual brakes was slightly less than that of the standard car at speeds below 40 mph. This was an unexpected result; it shows that the adhesion demand for the dual-braked cars was more consistent with available adhesion at low speeds.

Available adhesion increases at low speeds, but the adhesion demands of Amcoaches increase sharply at lower speeds. Therefore, the demand is very close to dry-rail conditions. The reduction in demand (displayed at the lower speeds by the dual-brake systems) means that there would be fewer occasions when the wheels tend to slide. The slide control system prevents serious slides but the wheel has to slide a short distance before the system can detect that the wheel is about to slide. Some damage is done every time the wheel begins to slide. This type of small damage produces spalling on the tread surface. Therefore, preventing small slides would save many wheel-tread defects.

All of the tests show that the Amcoaches have a relatively high deceleration rate which means that the adhesion demands may often exceed the available wheel/rail adhesion for wet rail or other marginal rail conditions.

The test results showed that the special reduced-pressure braking produced a significant reduction in adhesion demand at very slow speeds where full-service, brake-cylinder pressure on the standard car caused the car to approach the limits of available dry-rail adhesion.

The results of the single-car cutaway tests on the standard car (No. 21018) are plotted in Figure 6-18 with the performance requirements specified in "Specification for Locomotive Propelled Cars to be Used in Corridor Type Passenger Service" (Budd Order No. 9600-760). Data comparisons at speeds below 40 mph seem to indicate that the braking rates of standard Amcoaches are much higher than the rates required by the car specification.

The normal dual-brake test showed that the dual brakes performed as expected and reduced disc temperatures, thereby providing added thermal capacity to the brake system. The disc brakes did an excellent job of cleaning the wheel tread and the system produced the unexpected advantage of reducing wheel/rail adhesion demands at slow speeds.

The addition of tread brakes produced significant improvements in the tread surfaces. Tread brakes also reduce rim vibrations and can be predicted to reduce wheel slide even if system response does not reshape the deceleration curves to reduce adhesion requirements at lower speeds. The reductions displayed by each of the systems should reduce wheel slide for cars equipped with dual brakes. These systems are less demanding in the area of wheel/rail adhesion at lower speeds, but they maintain the overall braking rates (equivalent to a normal Amcoach operated at 68-psi brake cylinder pressure).

The performance of the dual-brake systems would appear to make these systems strong contenders for service at 120 mph on the Northeast Corridor. More significant reductions in adhesion demand and potentially in wheel slide are expected when the dual-brake system is used.

Reducing full-service, brake-cylinder pressure appears to be a good interim solution to reducing wheel damage.

APPENDIX A

STOPPING DISTANCE CURVES

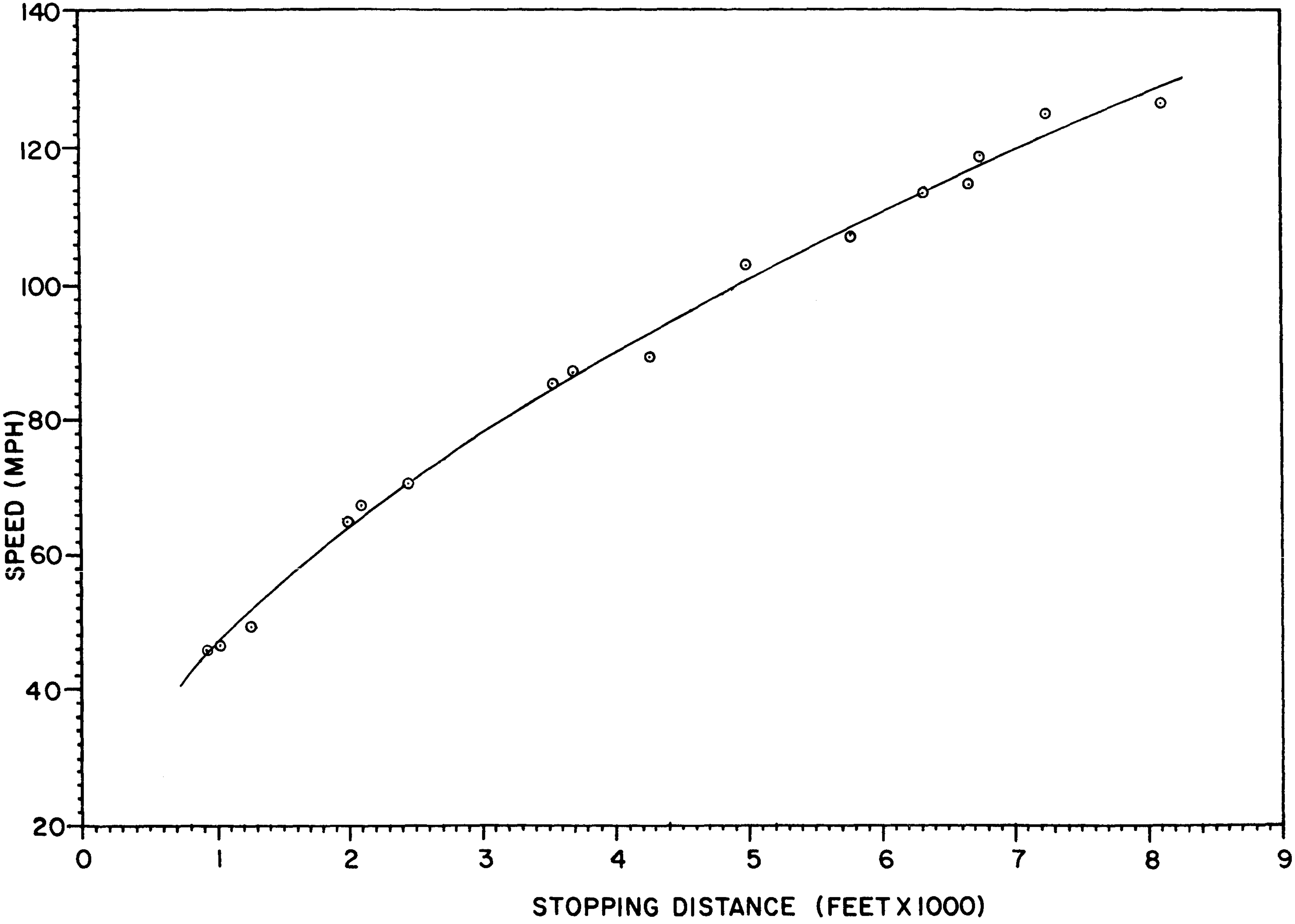

FIGURE A-1
Stopping Distance (Half-Service Braking) -
Standard Car No. 21013

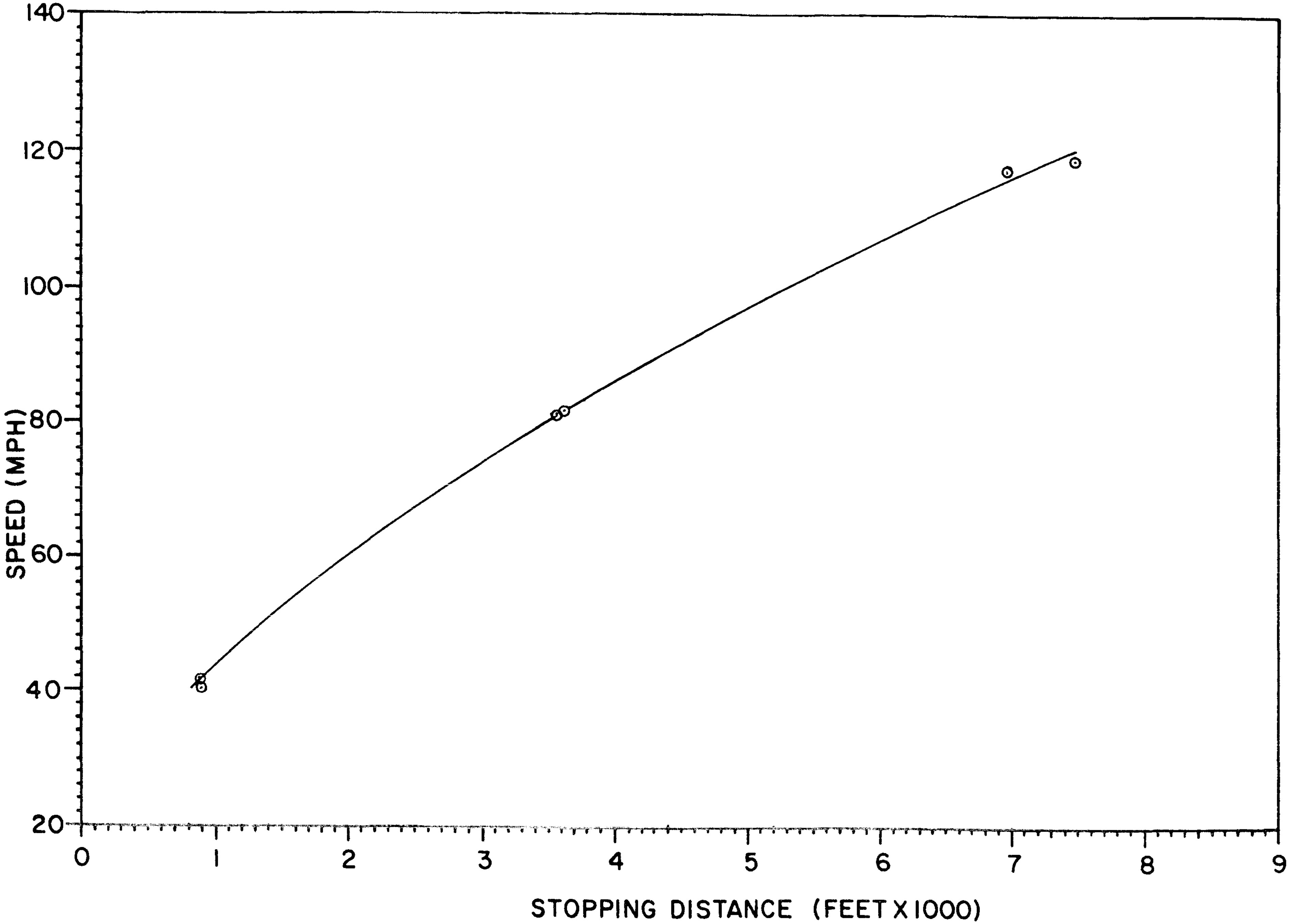

FIGURE A-2
Stopping Distance (Half-Service Braking) -
Car No. 21044 - 50/50 Disc/Tread Ratio

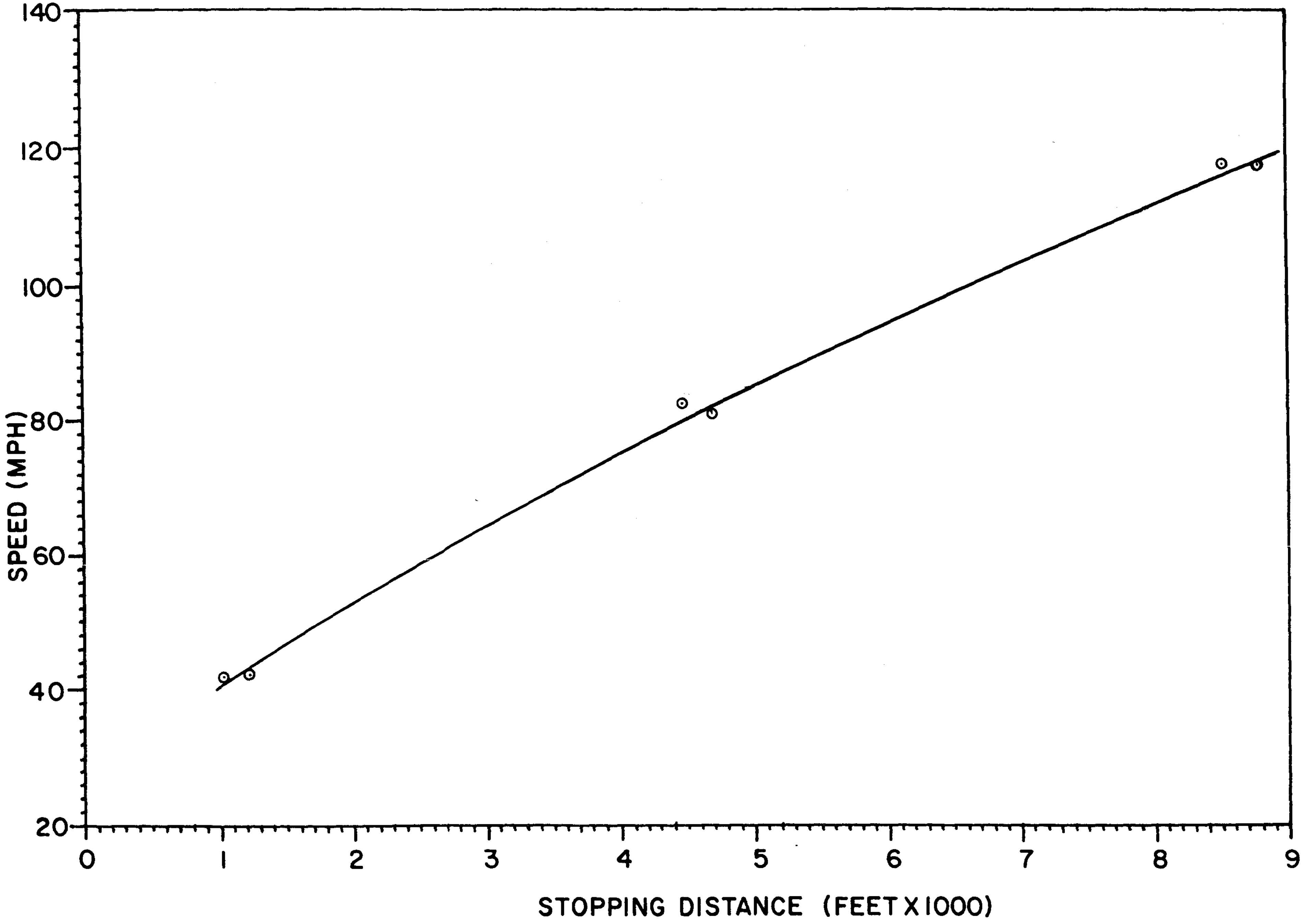

FIGURE A-3
Stopping Distance (Half-Service Braking) -
Car No. 21044 - 60/40 Disc/Tread Ratio

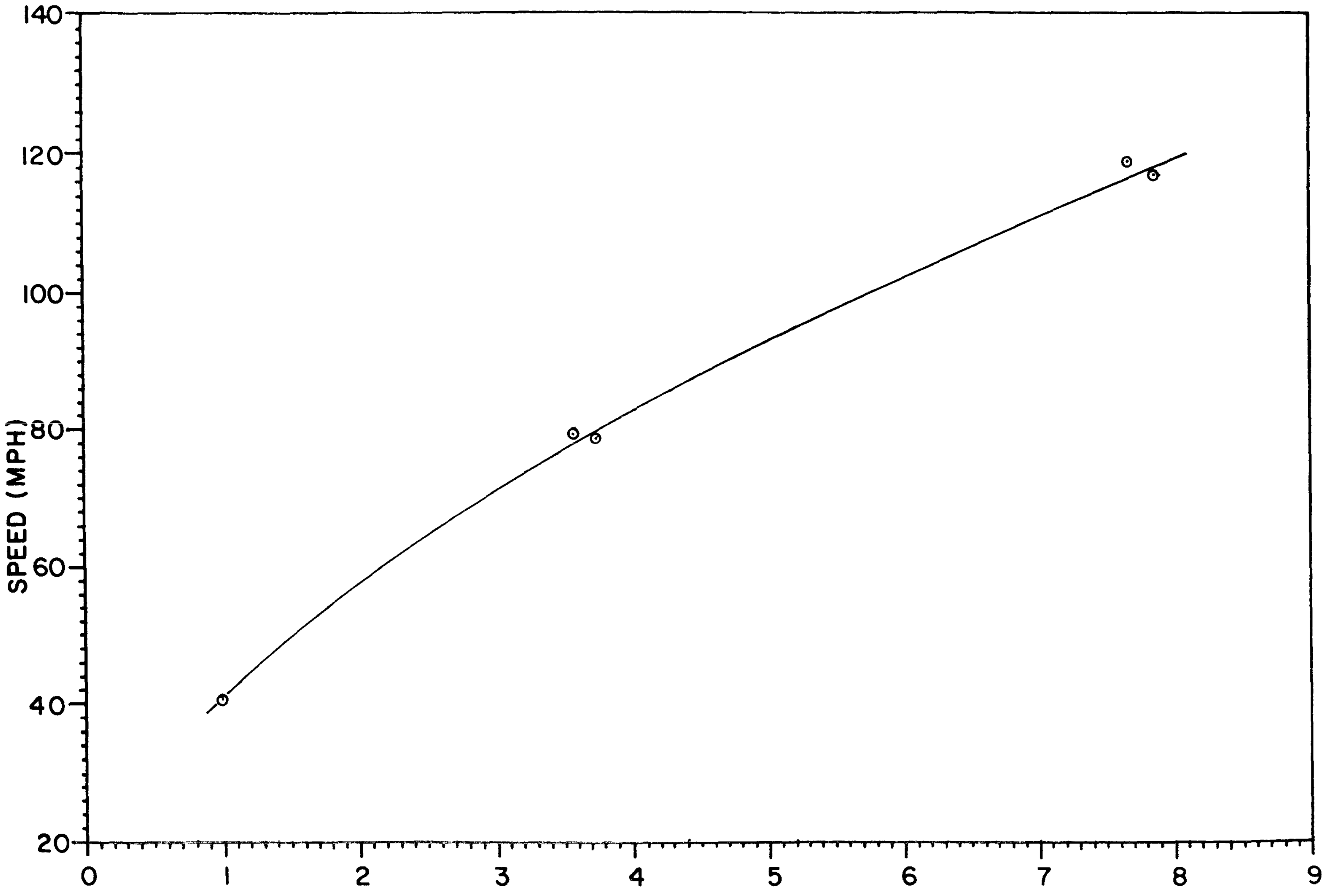

FIGURE A-4
Stopping Distance (Half-Service Braking) -
Car No. 21063 - 50/50 Disc/Tread Ratio

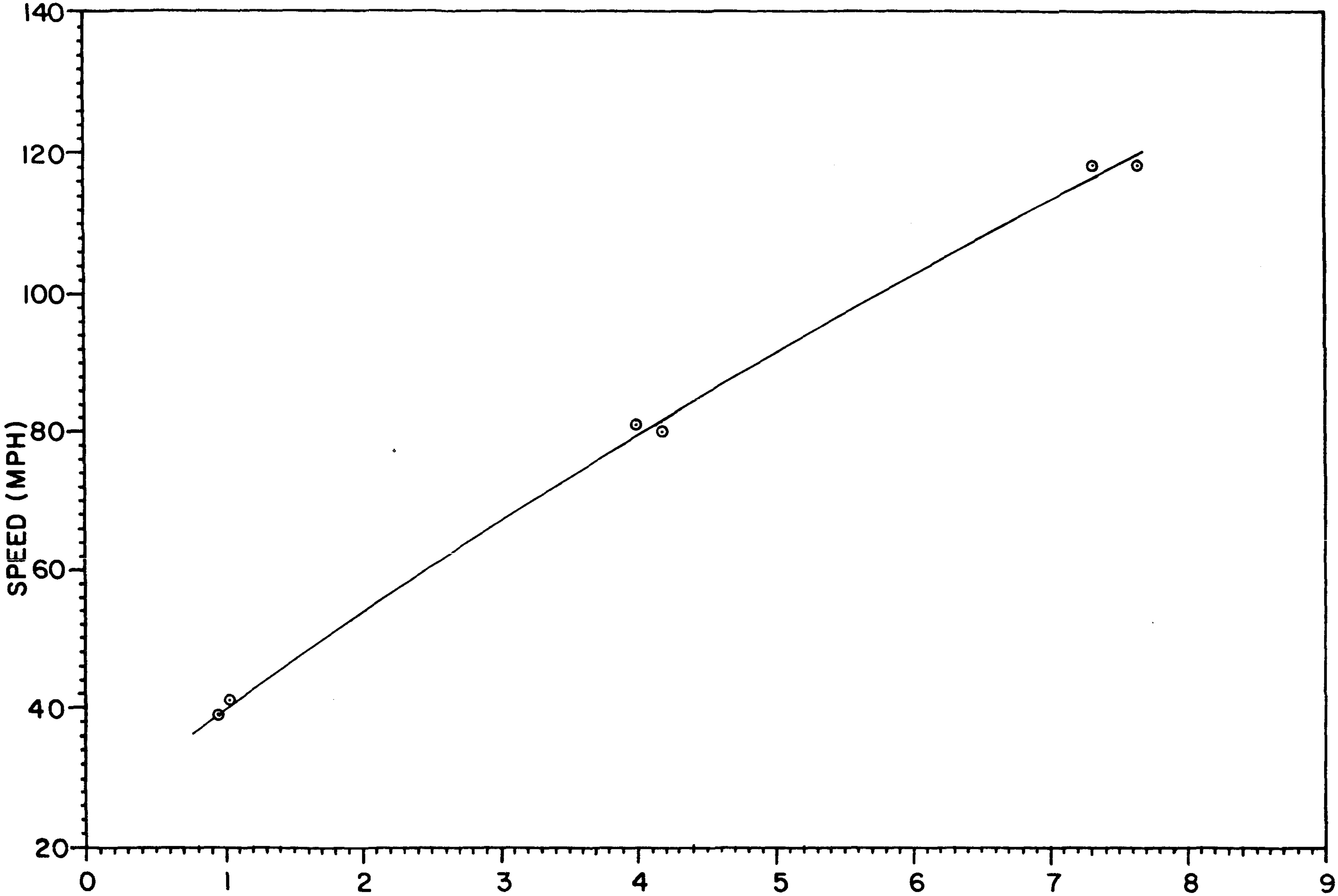

FIGURE A-5
Stopping Distance (Half-Service Braking) -
Car No. 21063 - 60/40 Disc/Tread Ratio

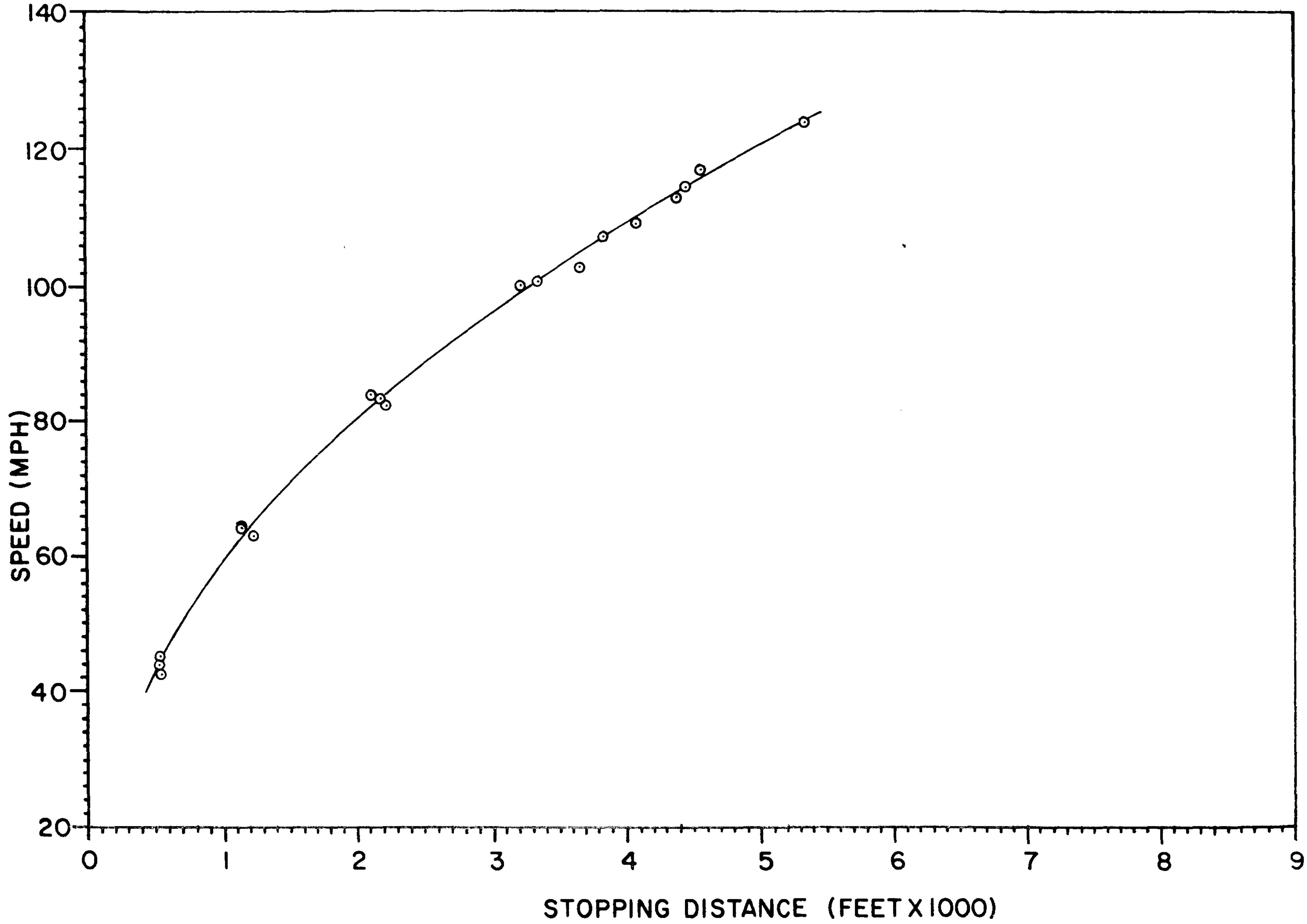

FIGURE A-6
Stopping Distance (Full-Service Braking) -
Standard Car No. 21018

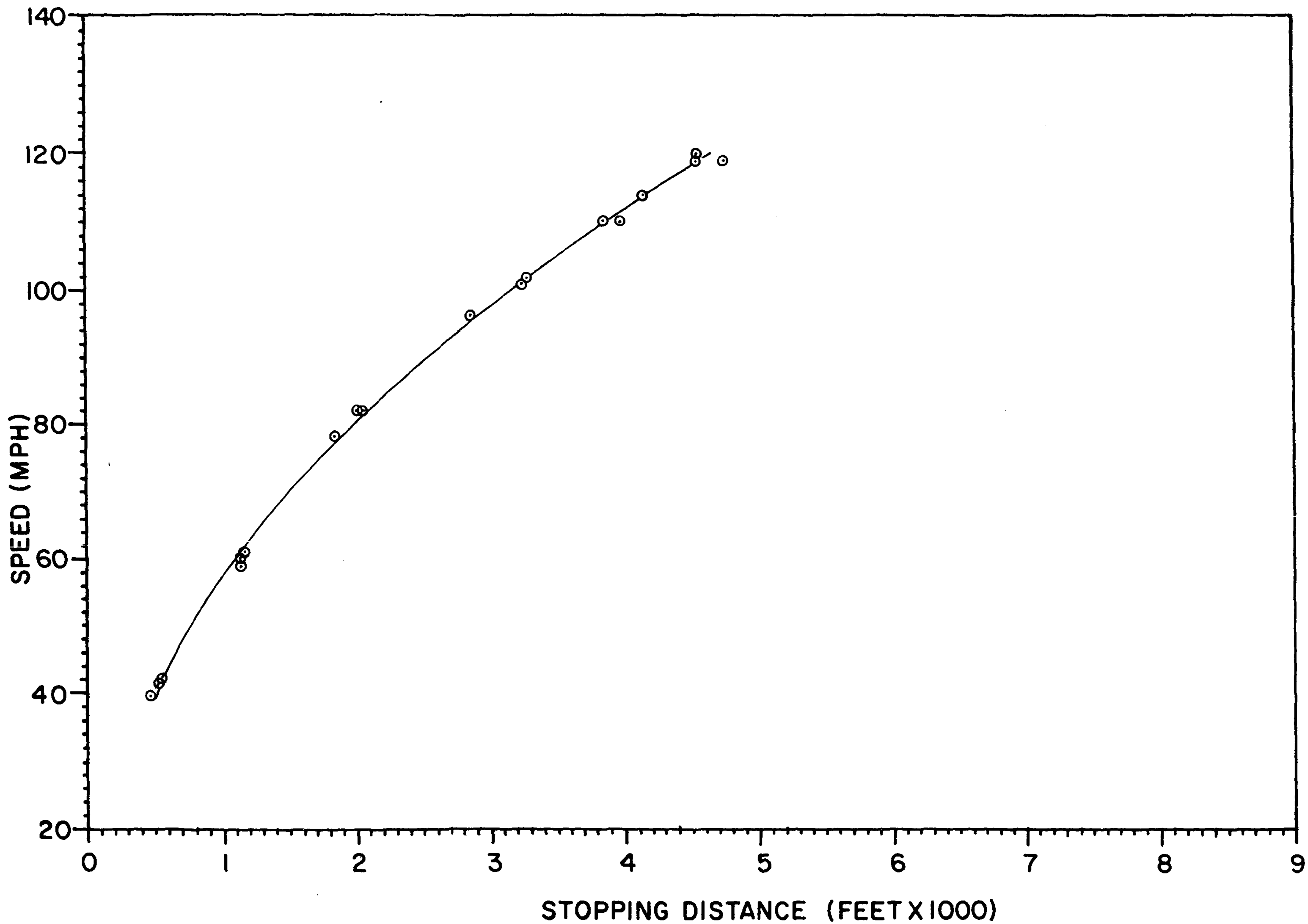

FIGURE A-7
Stopping Distance (Full Service Braking) -
Car No. 21044 - 50/50 Disc/Tread Ratio

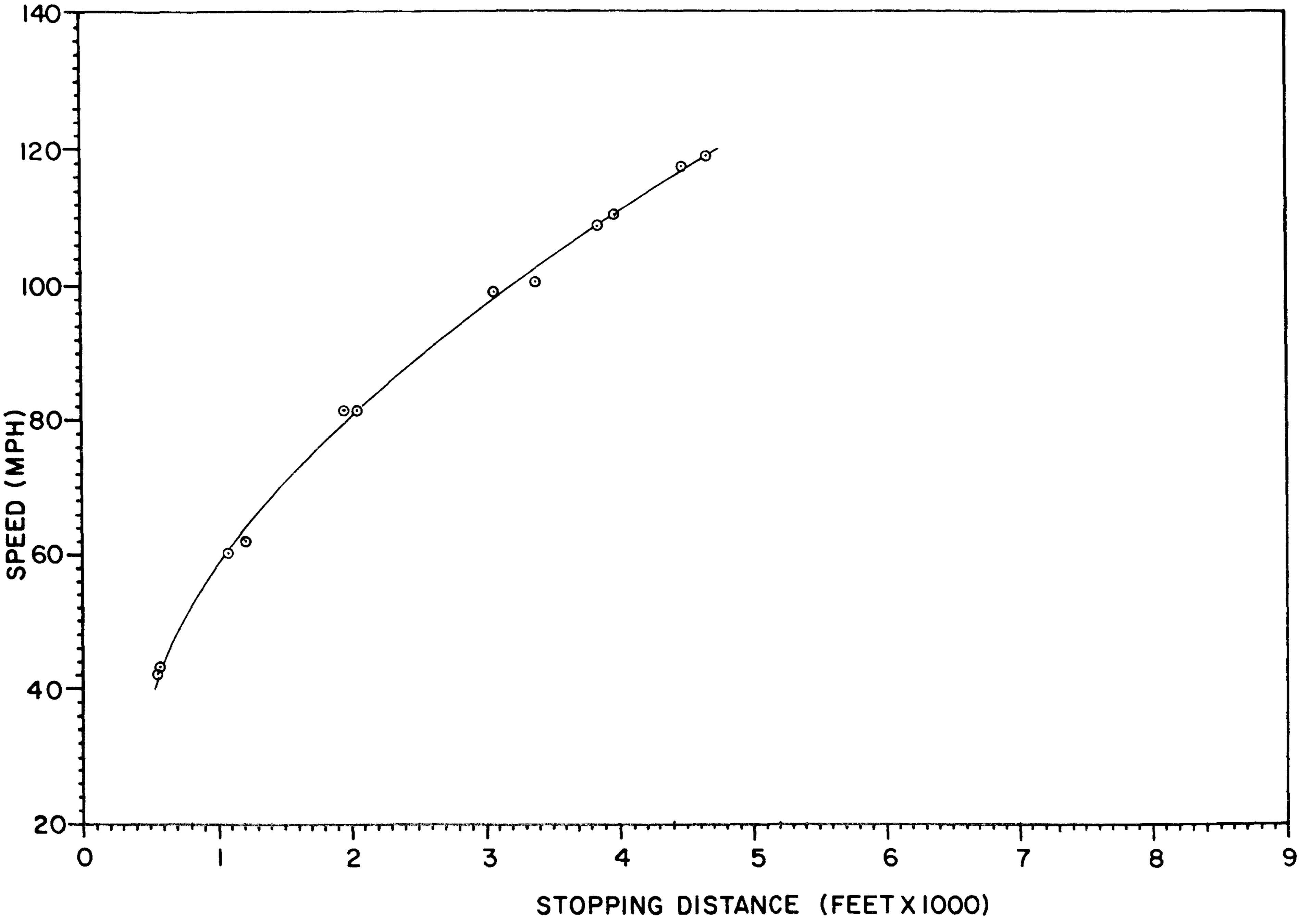

FIGURE A-8
Stopping Distance (Full-Service Braking) -
Car No. 21044 - 60/40 Disc/Tread Ratio

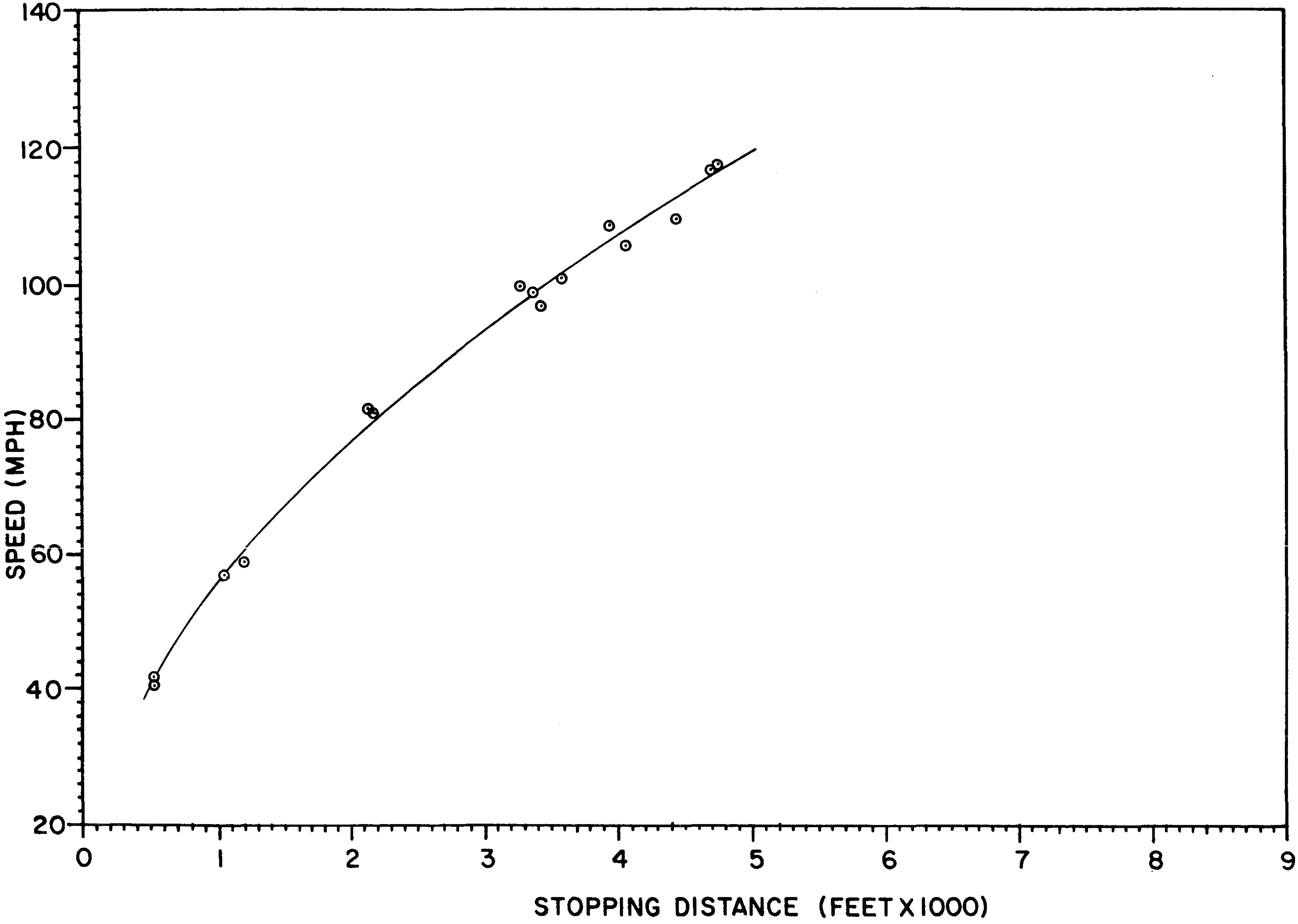

FIGURE A-9
Stopping Distance (Full-Service Braking) -
Car No. 21063 - 50/50 Disc/Tread Ratio

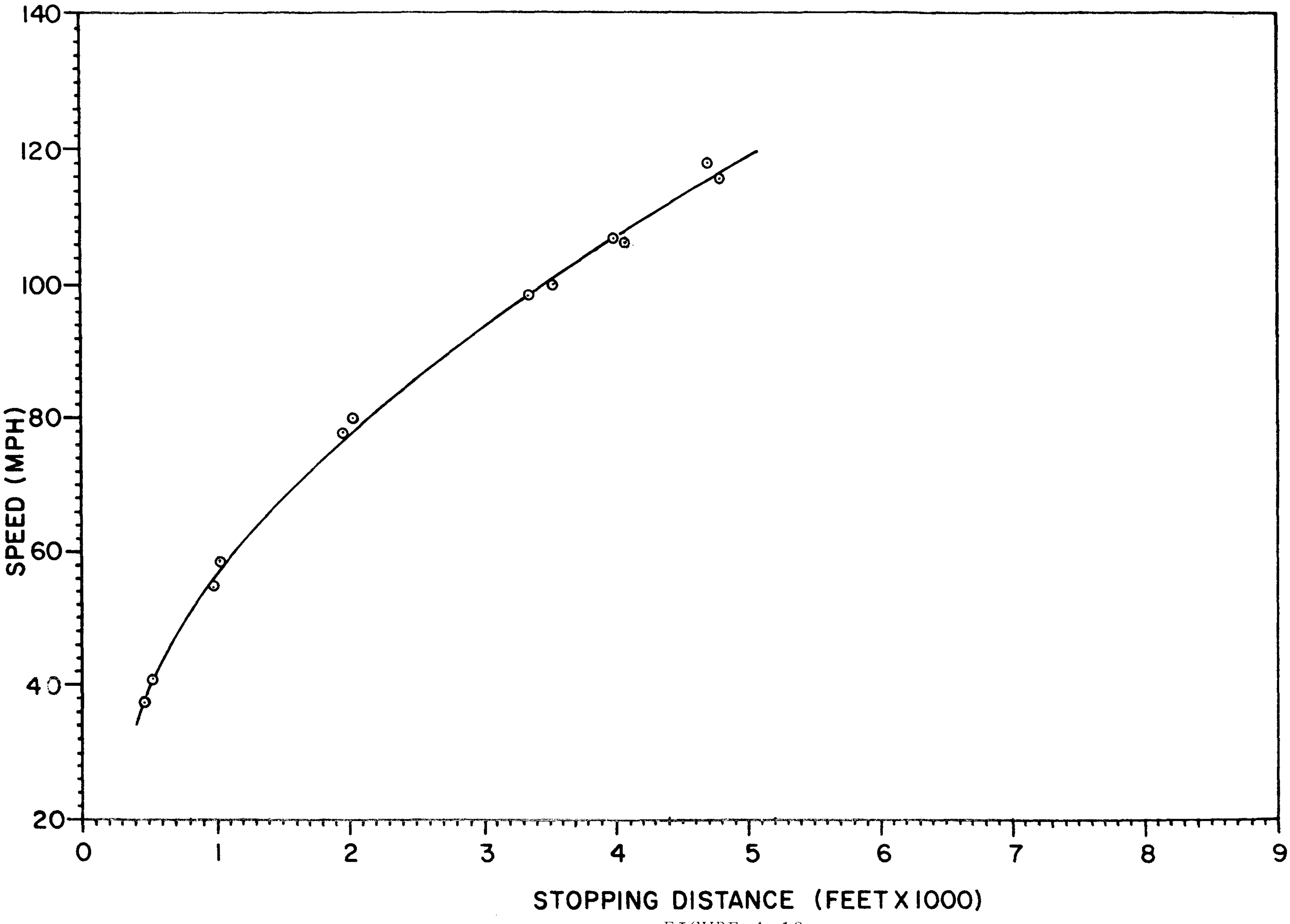

FIGURE A-10
Stopping Distance (Full-Service Braking) -
Car No. 21063 - 60/40 Disc/Tread Ratio

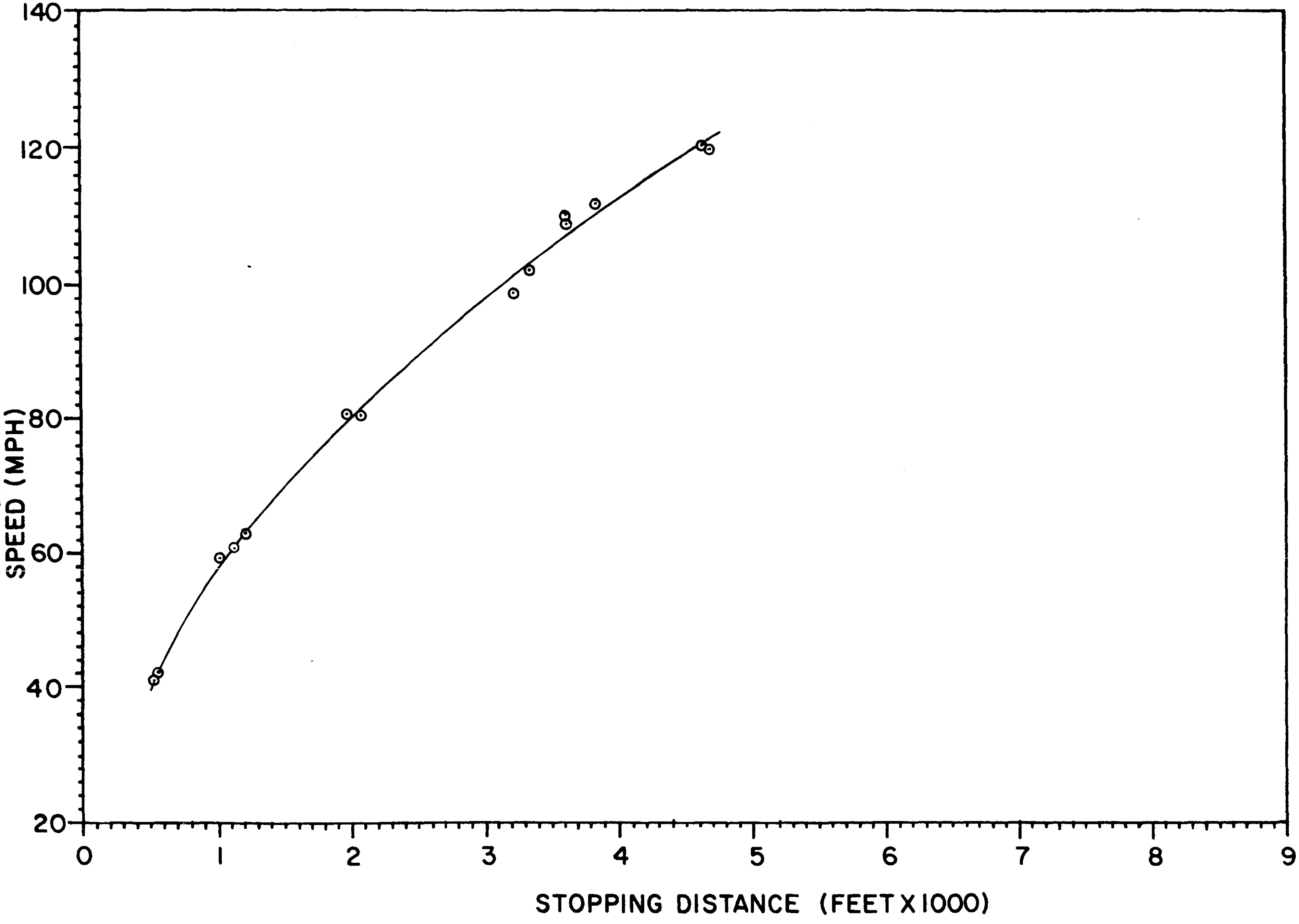

FIGURE A-11
Stopping Distance (Full-Service Braking) -
Car No. 21087 - 70/30 Disc/Tread Ratio

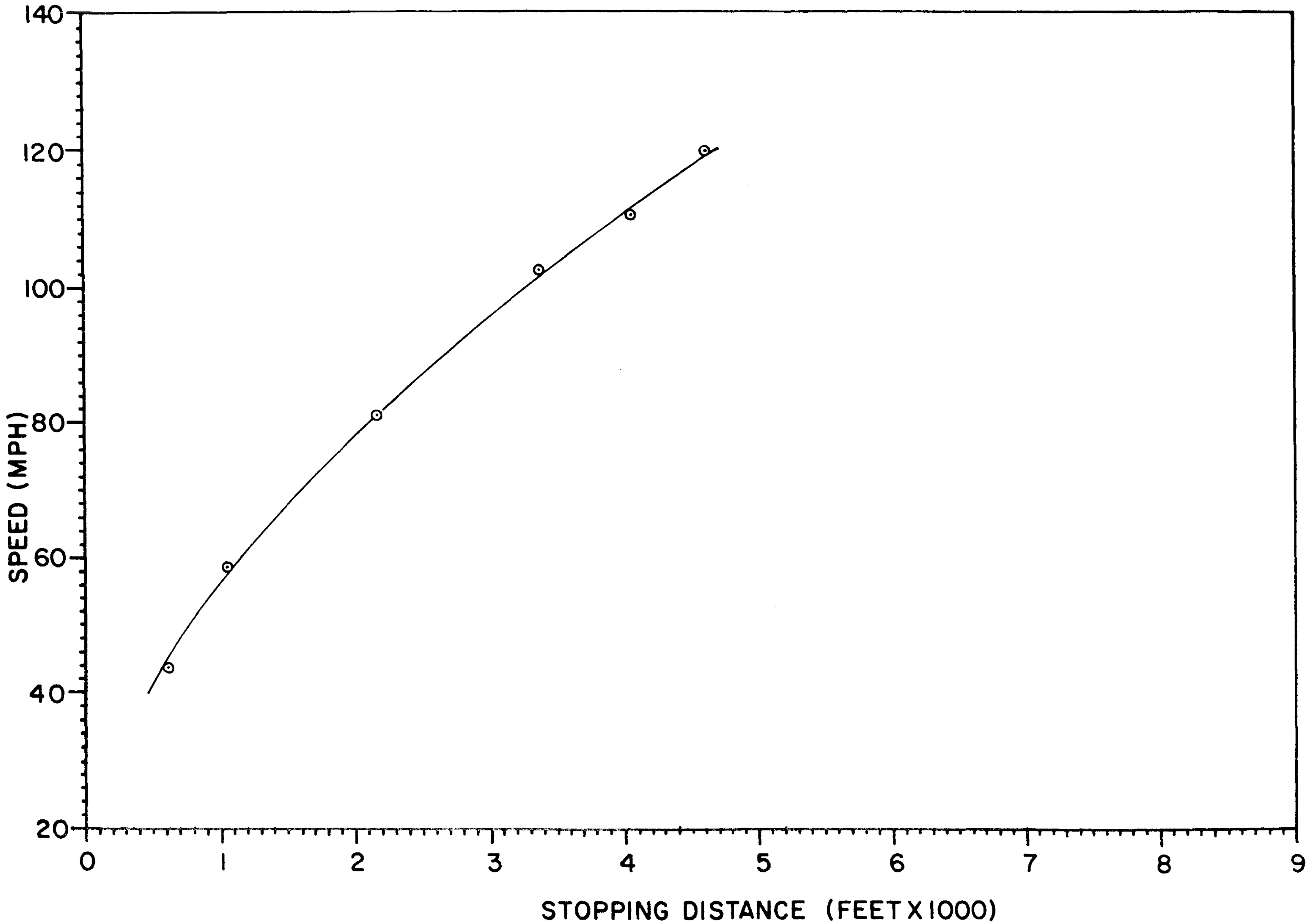

FIGURE A-12
Stopping Distance (Full-Service Braking) -
Car No. 21087 - 60/40 Disc/Tread Ratio

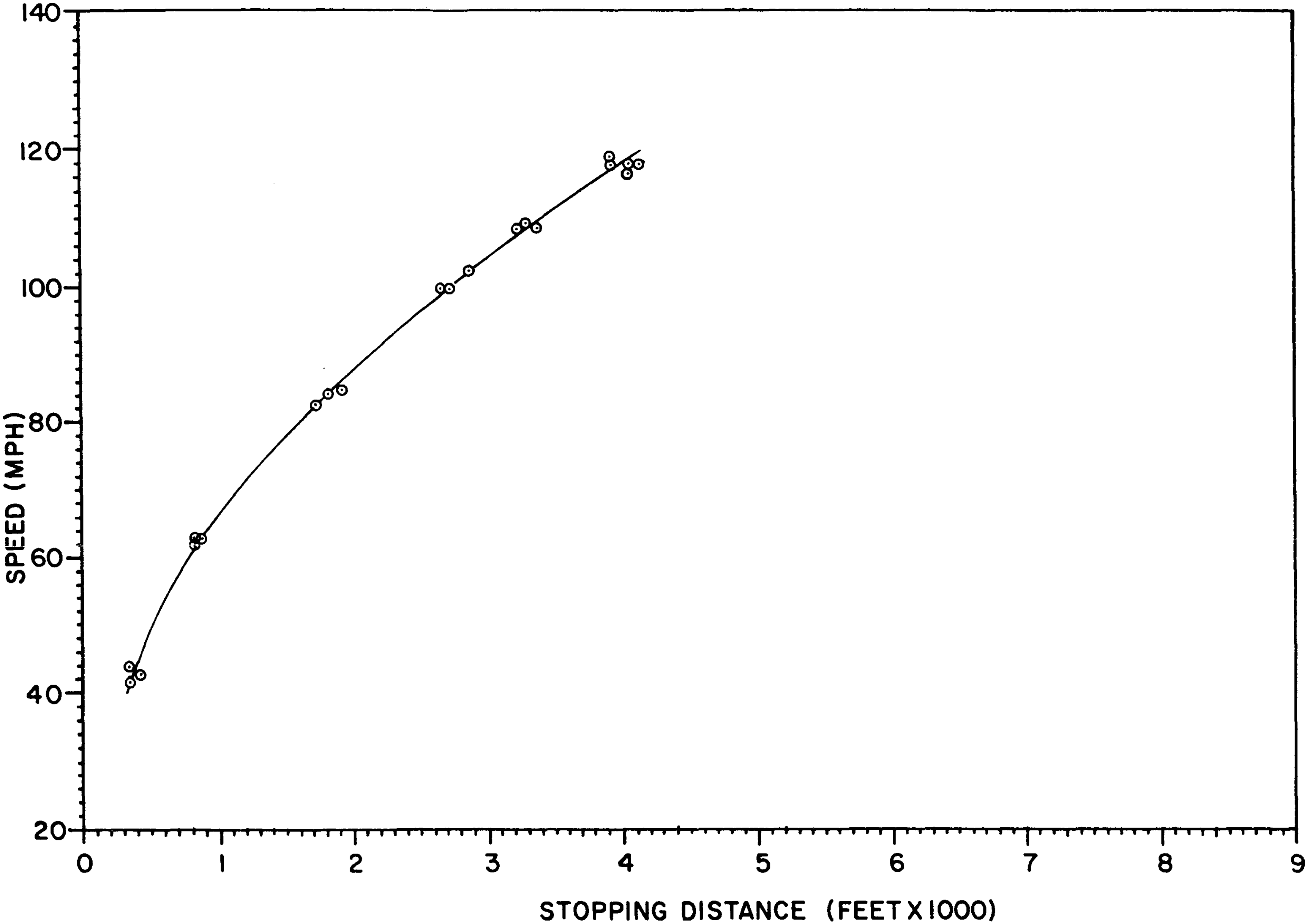

FIGURE A-13
Stopping Distance (Emergency Service) -
Standard Car No. 21018

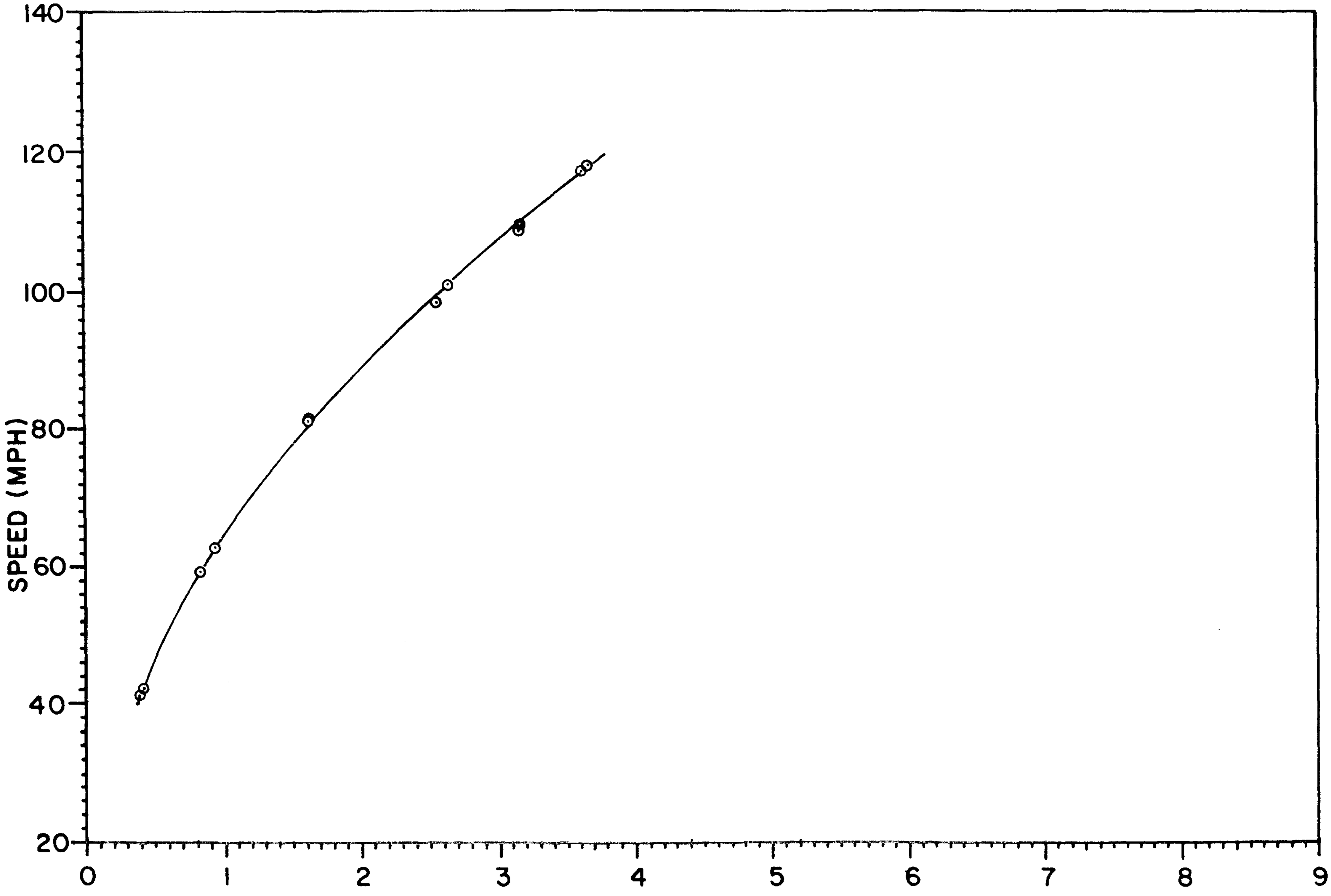

FIGURE A-14
Stopping Distance (Emergency Service) -
Car No. 21044 - 50/50 Disc/Tread Ratio

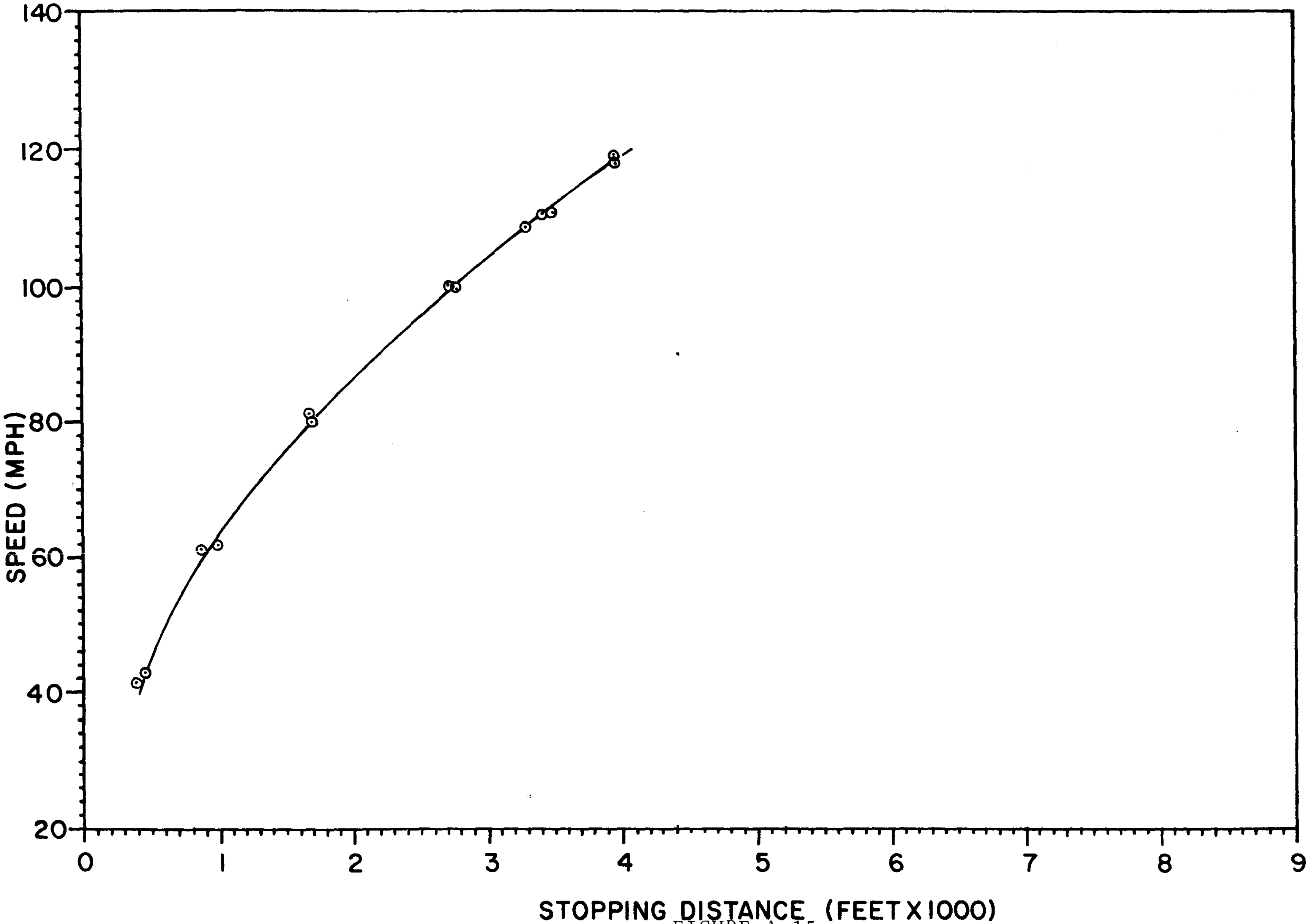

FIGURE A-15

Stopping Distance (Emergency Service) -
Car No. 21044 - 60/40 Disc/Tread Ratio

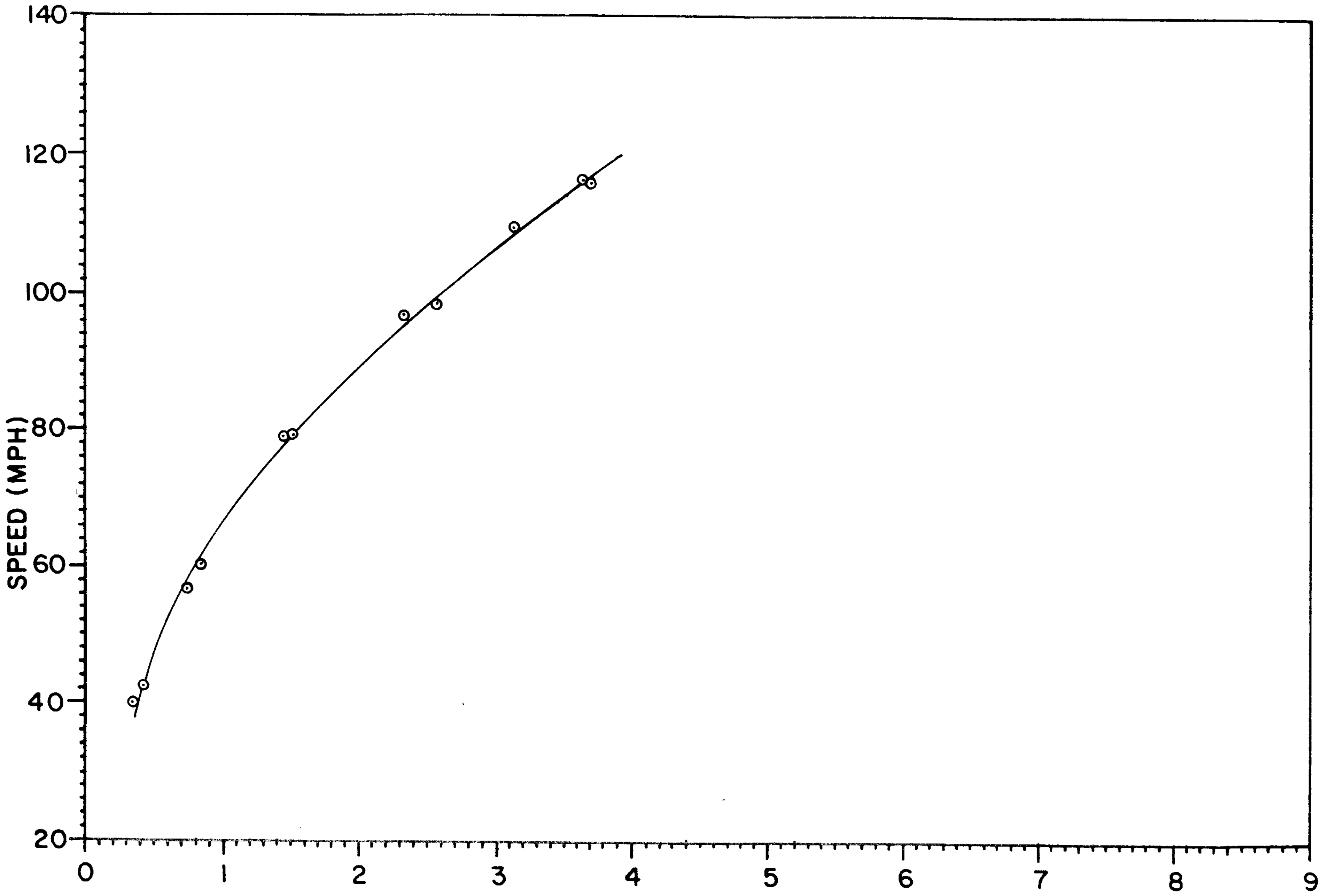

FIGURE A-16
Stopping Distance (Emergency Service) -
Car No. 21063 - 50/50 Disc/Tread Ratio

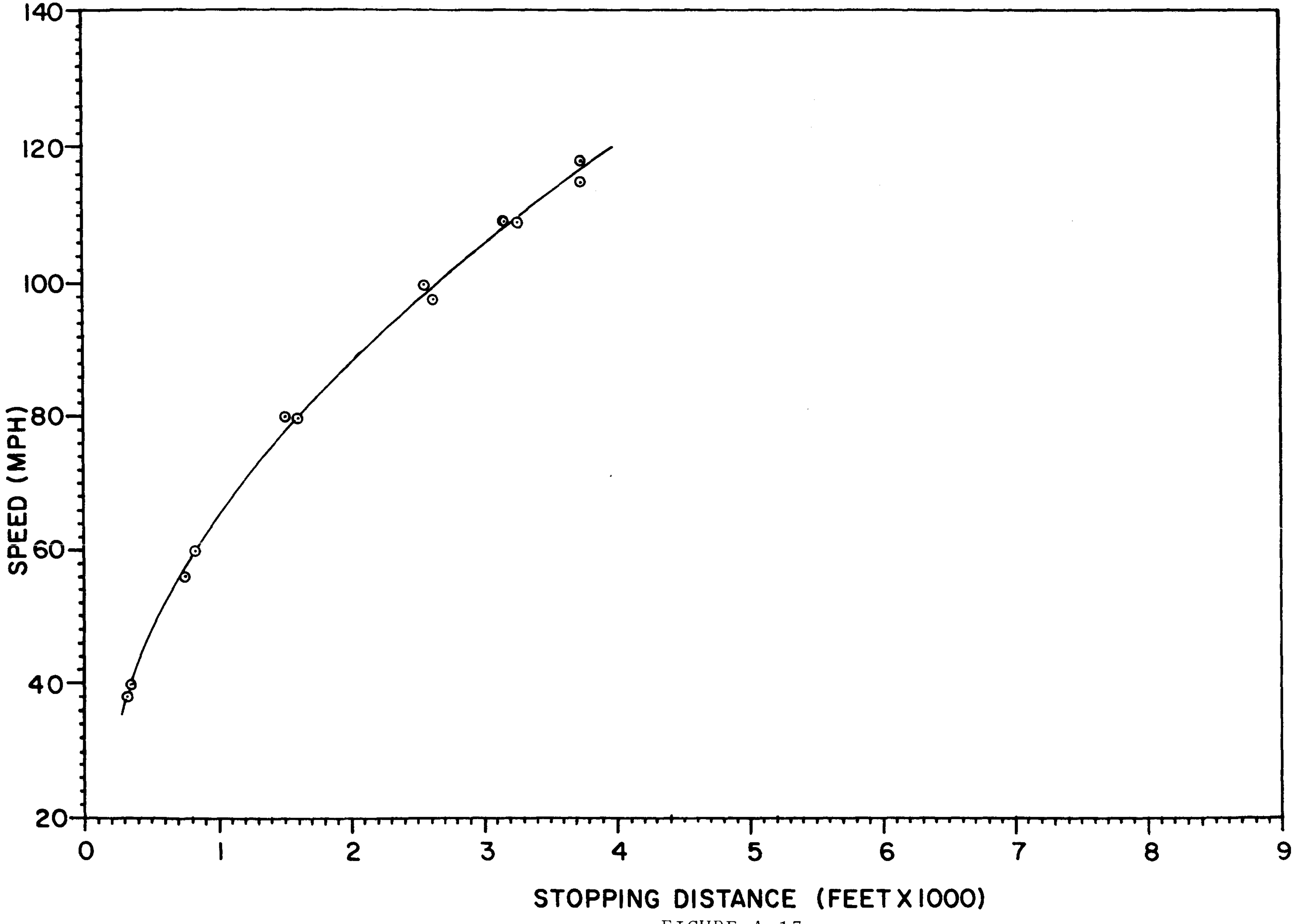

FIGURE A-17
Stopping Distance (Emergency Service) -
Car No. 21063 - 60/40 Disc/Tread Ratio

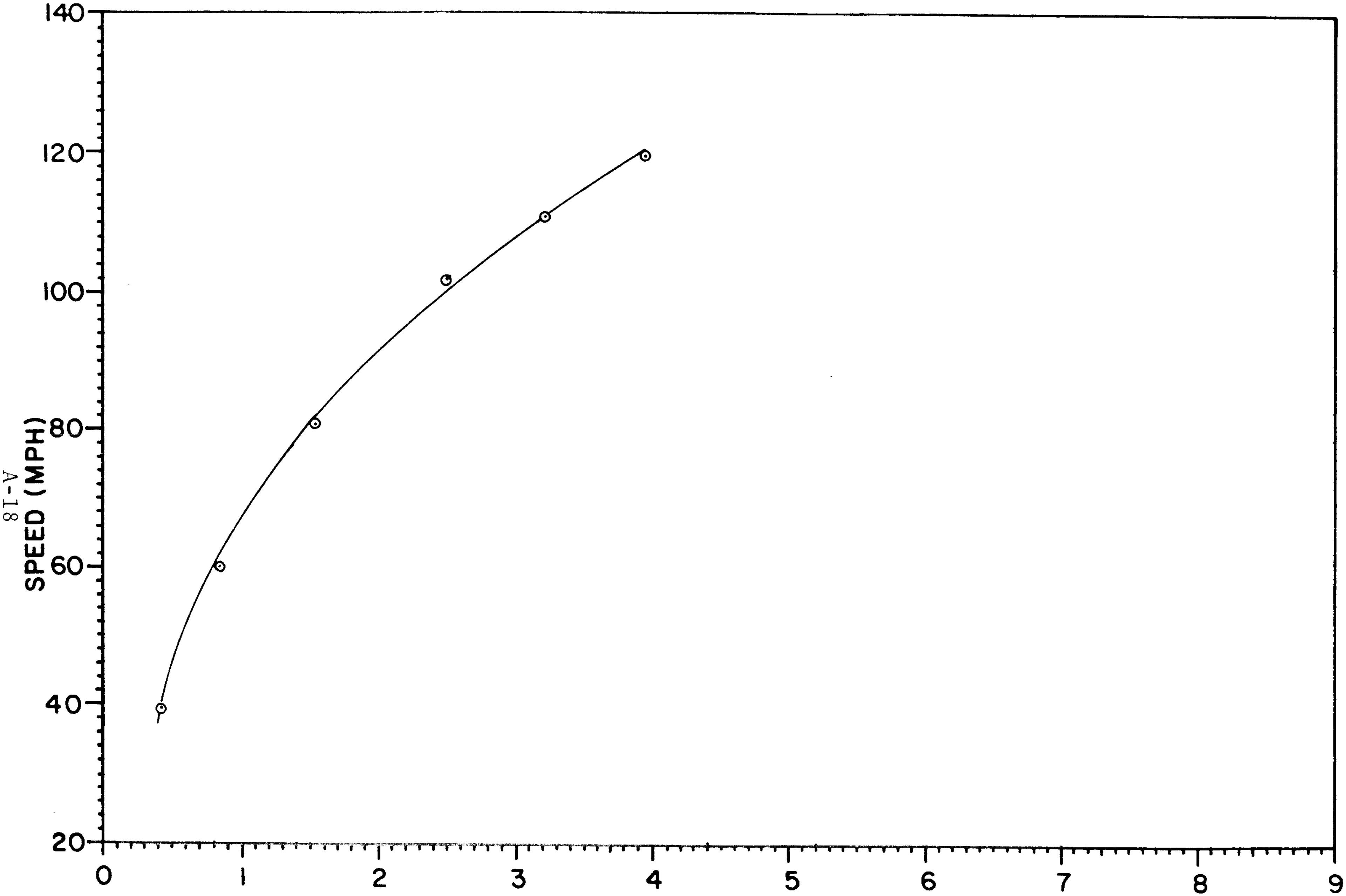

FIGURE A-18
Stopping Distance (Emergency Service) -
Car No. 21087 - 70/30 Disc/Tread Ratio

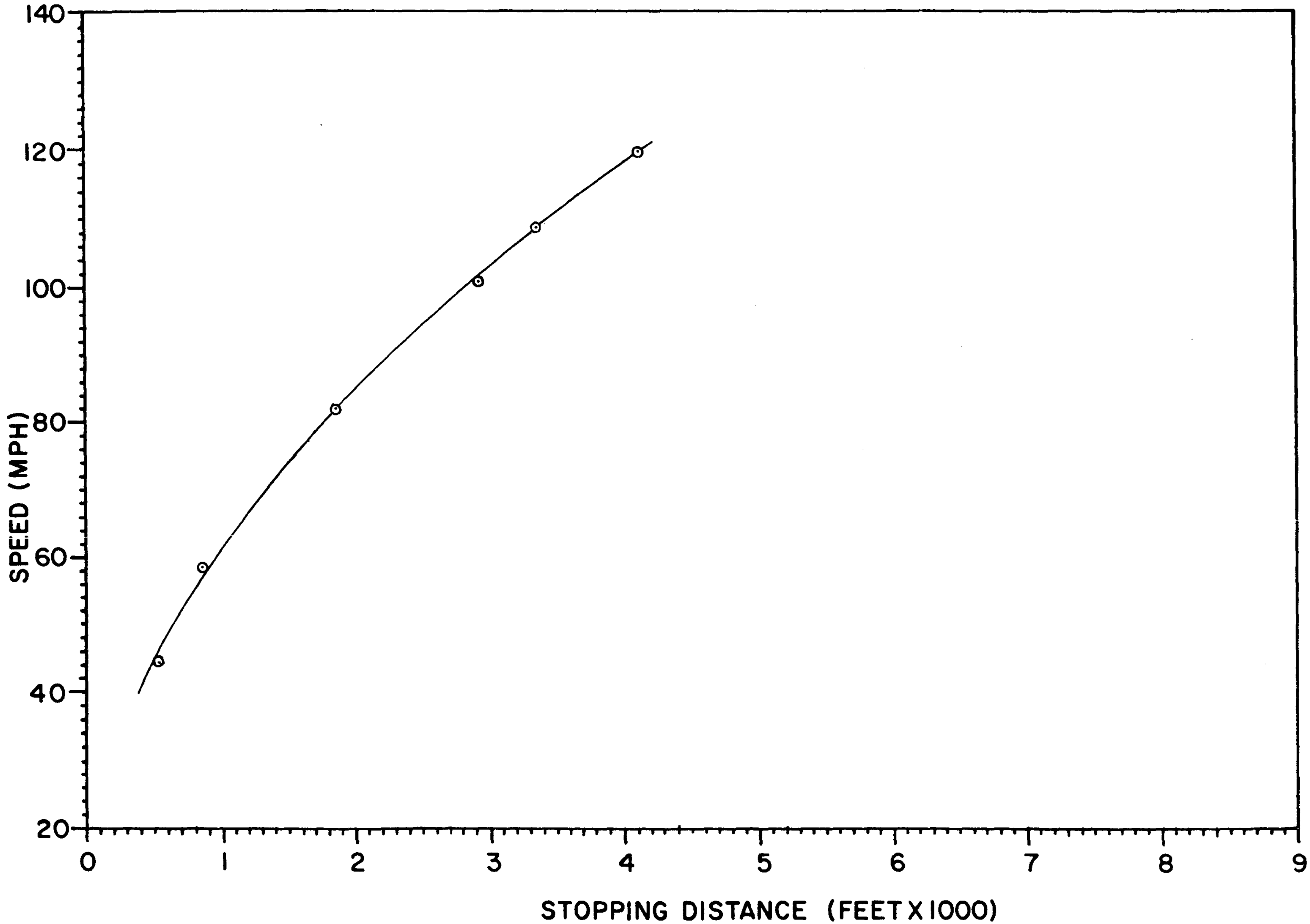

FIGURE A-19
Stopping Distance (Emergency Service) -
Car No. 21087 - 60/40 Disc/Tread Ratio

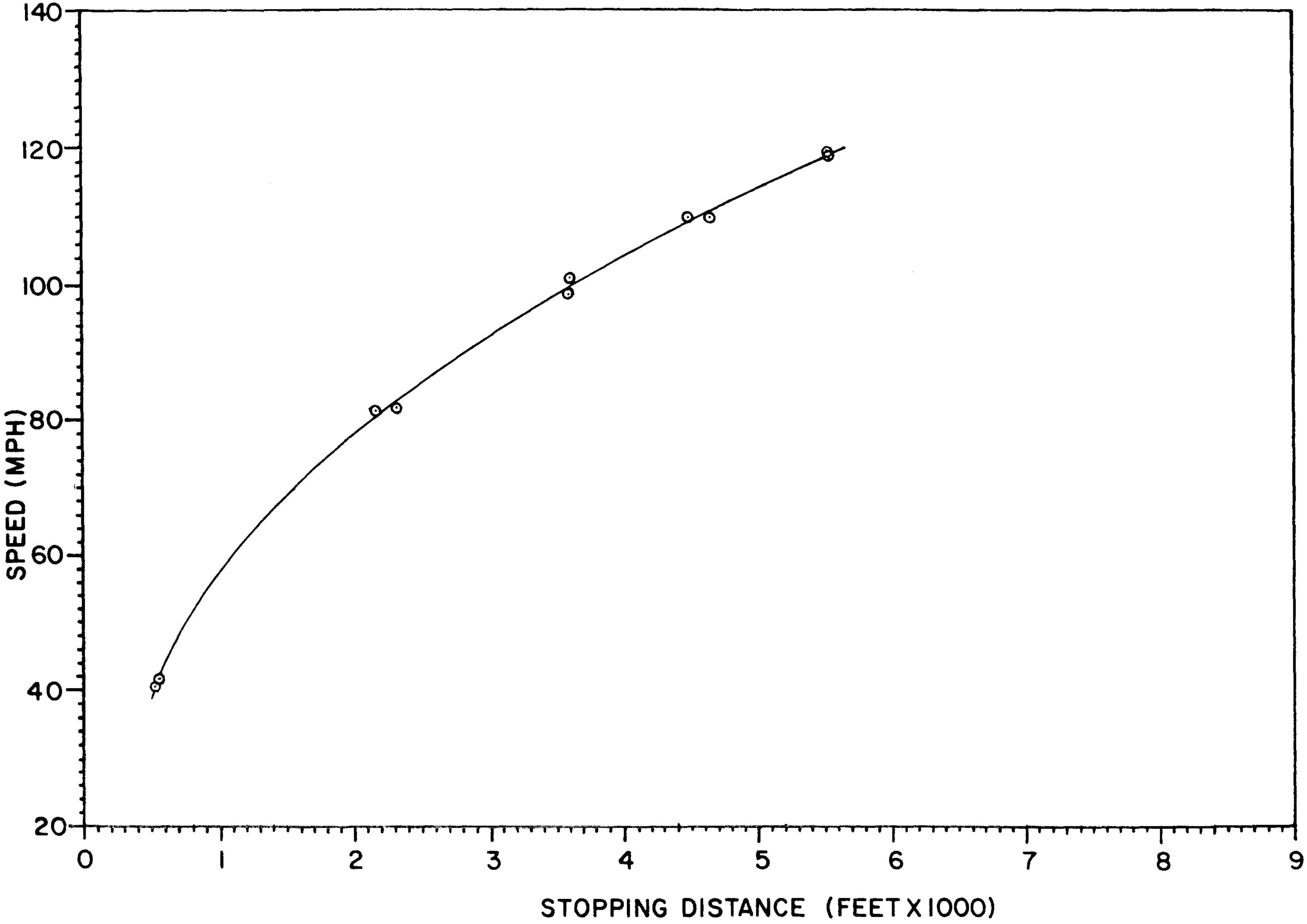

FIGURE A-20
Stopping Distance (Full Service Braking) -
Standard Car No. 21018

APPENDIX B

SPEED PROFILES

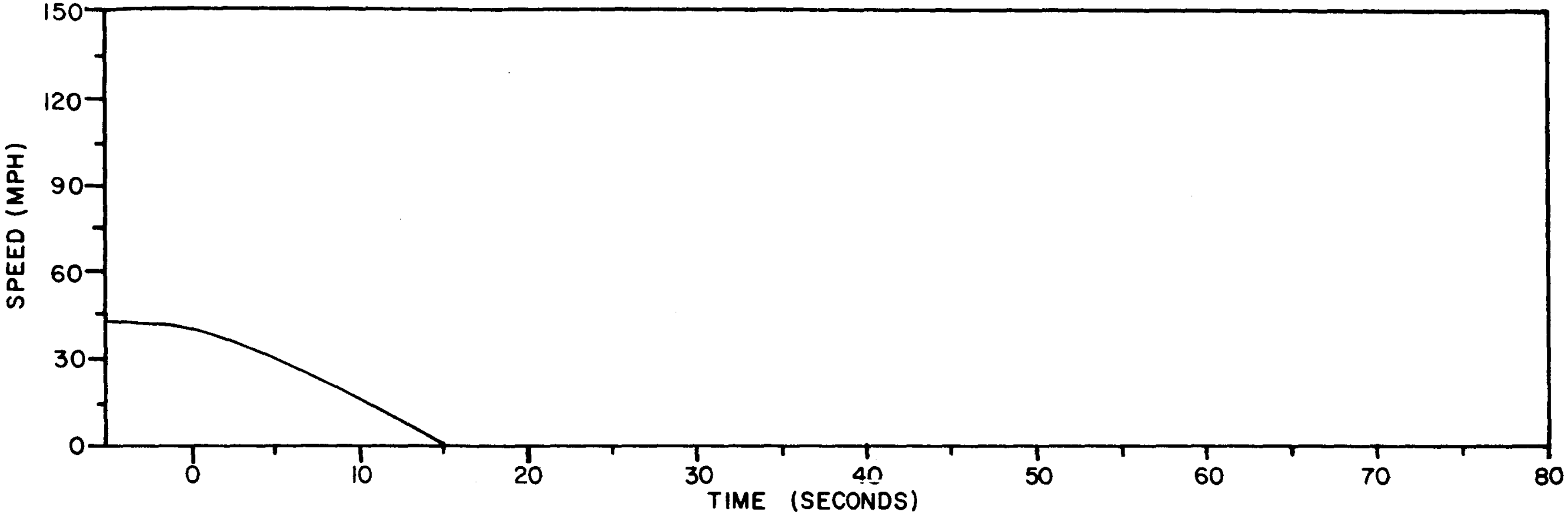

Figure B-1. Standard Car (No. 21018) - Full Service Braking - Run No. 112905

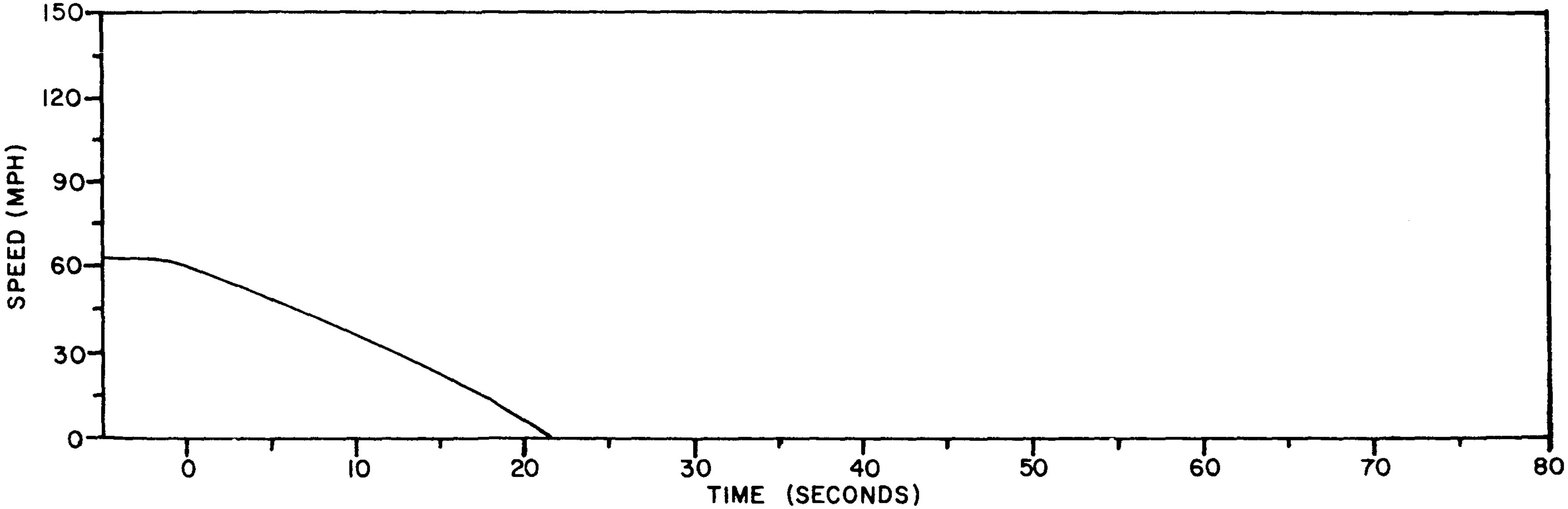

Figure B-2. Standard Car (No. 21018) - Full Service Braking - Run No. 112907

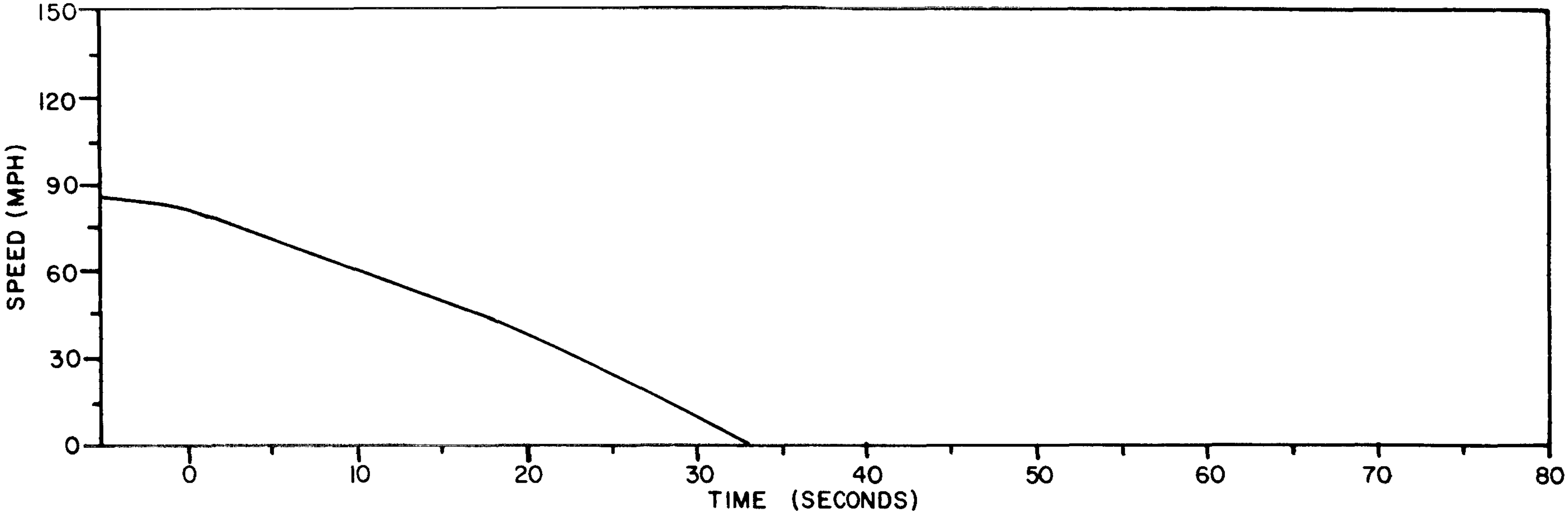

Figure B-3. Standard Car (No. 21018) - Full Service Braking - Run No. 112903

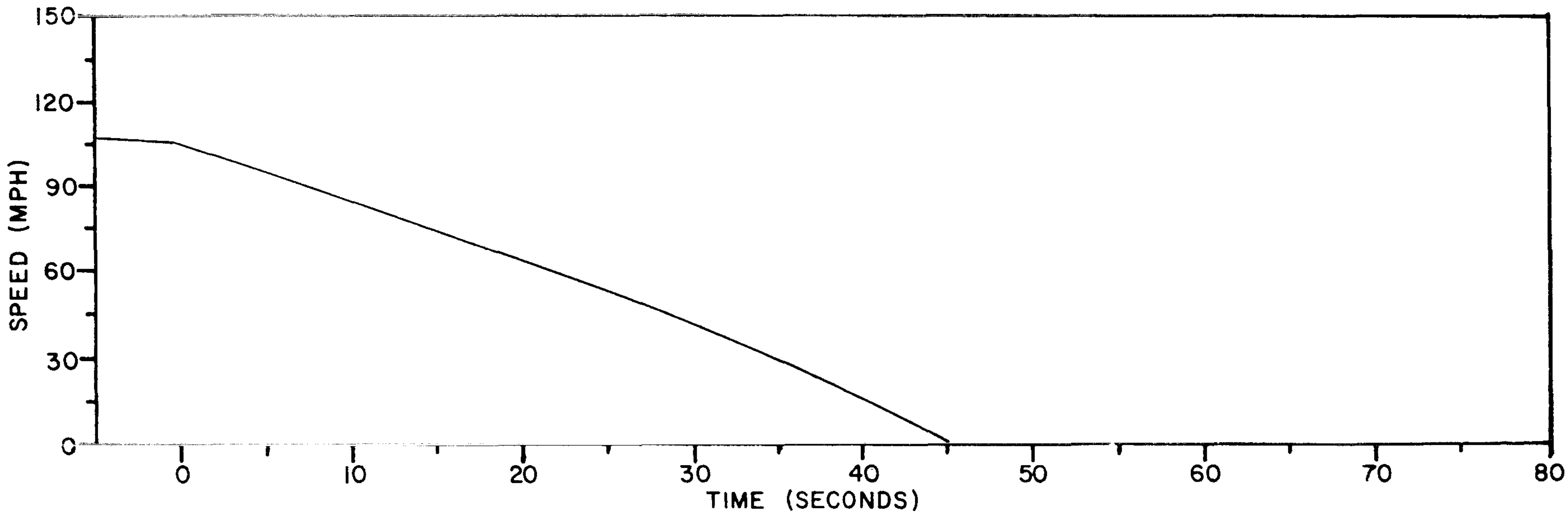

Figure B-4. Standard Car (No. 21018) - Full Service Braking - Run No. 112908

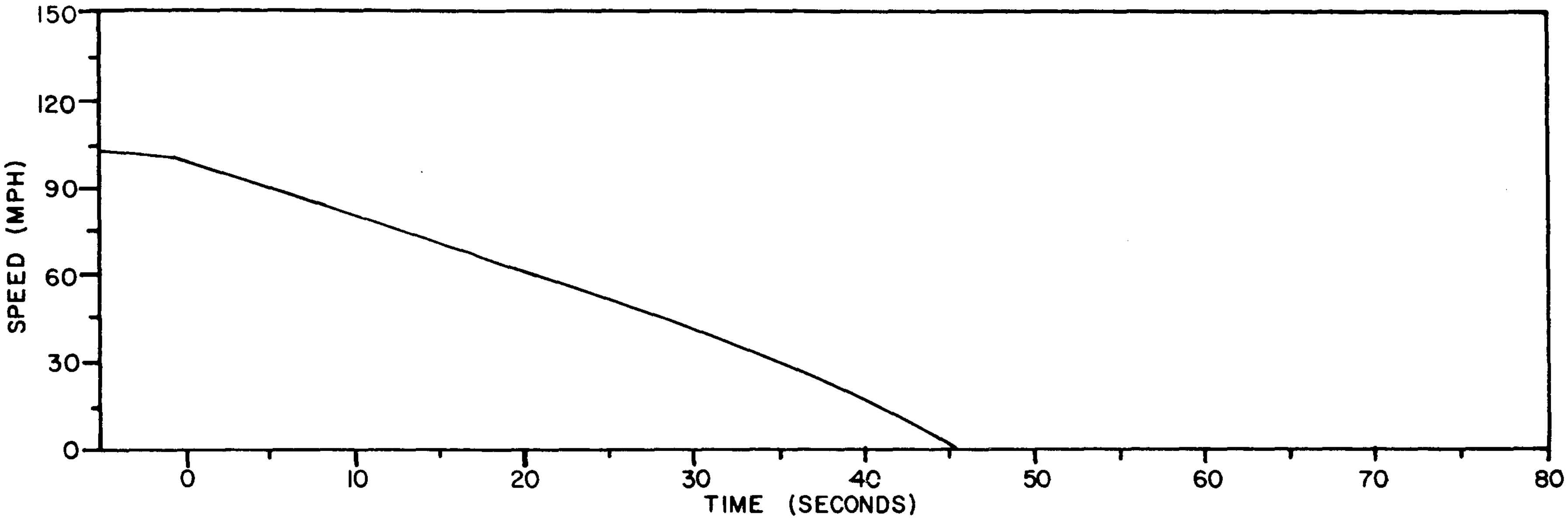

Figure B-5. Standard Car (No. 21018) - Full Service Braking - Run No. 112802

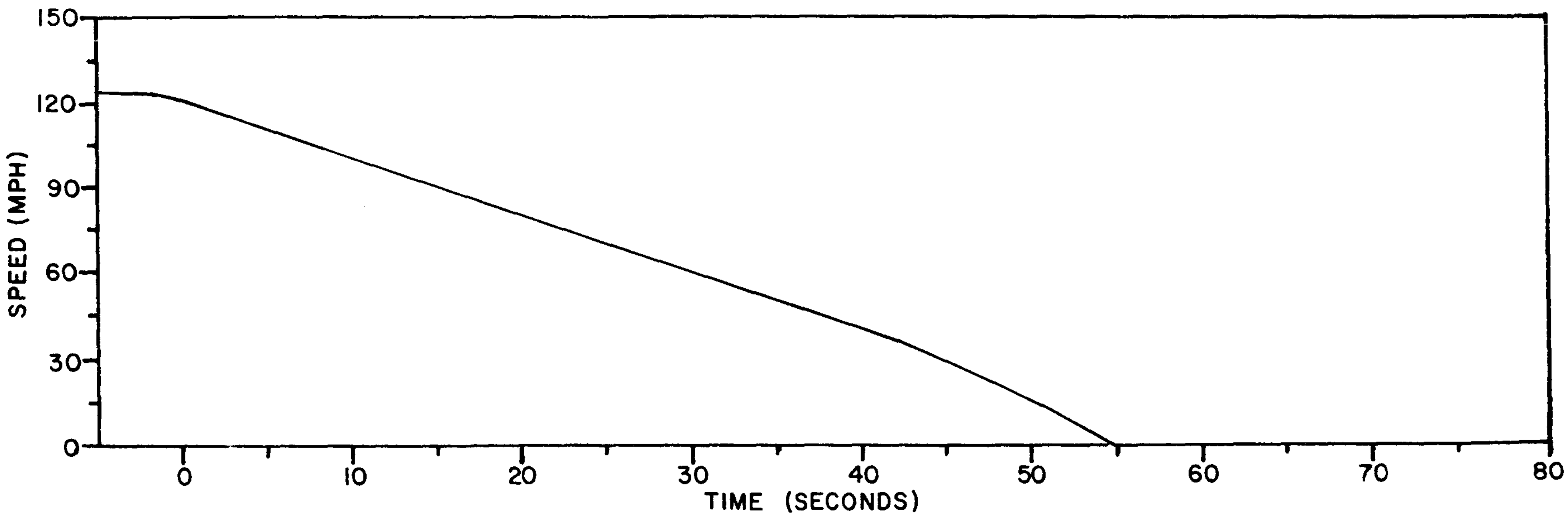

Figure B-6. Standard Car (No. 21018) - Full Service Braking - Run No. 112806

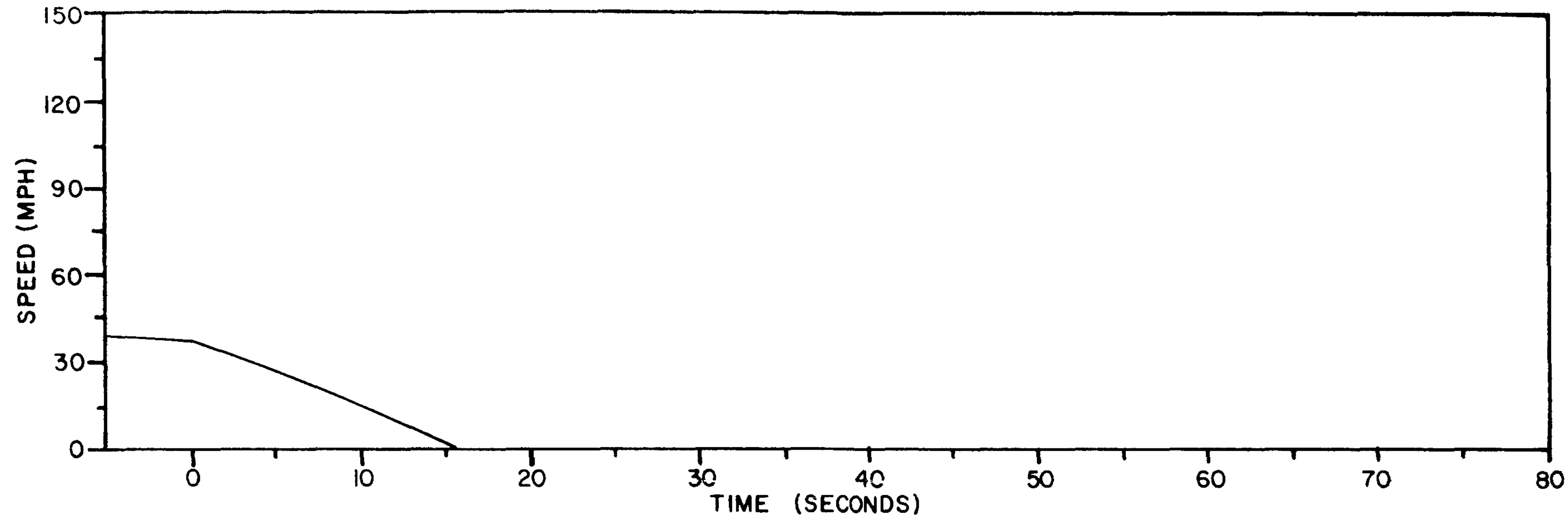

Figure B-7. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121010

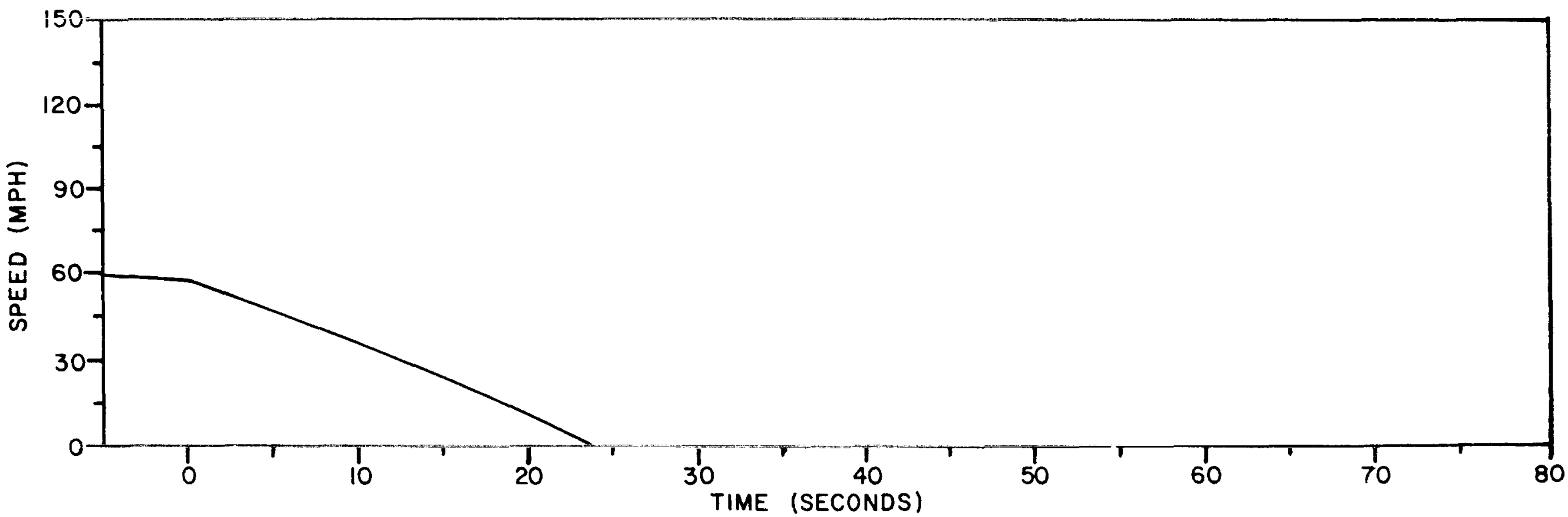

Figure B-8. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121012

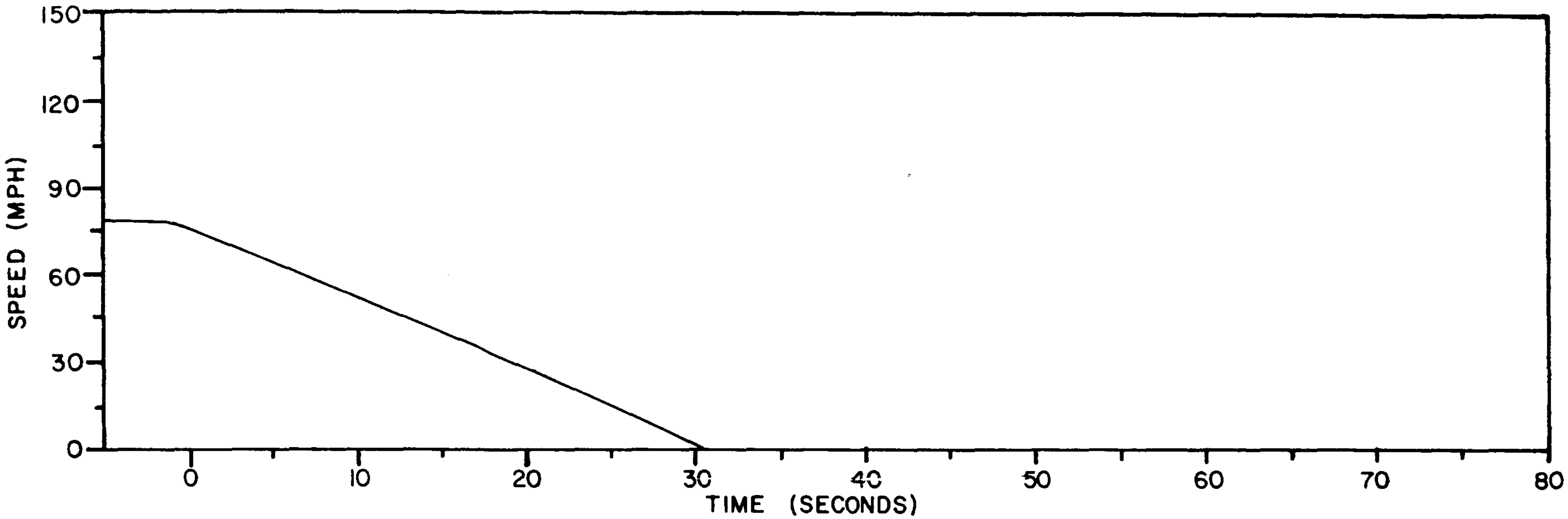

Figure B-9. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121008

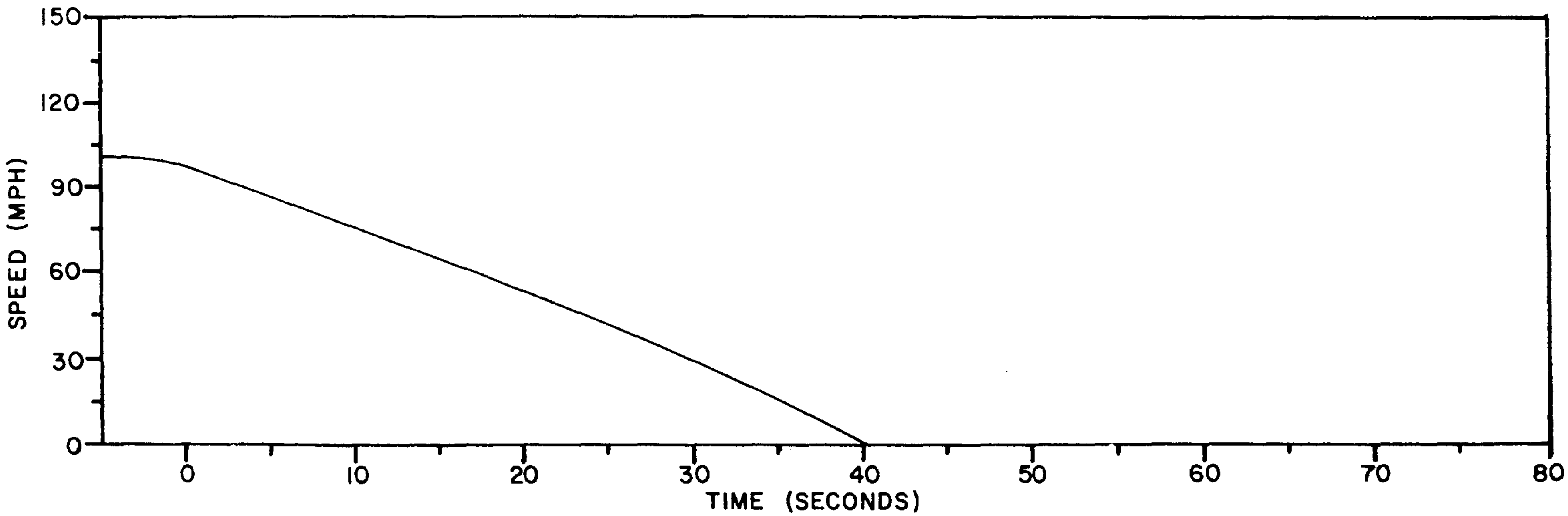

Figure B-10. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121111

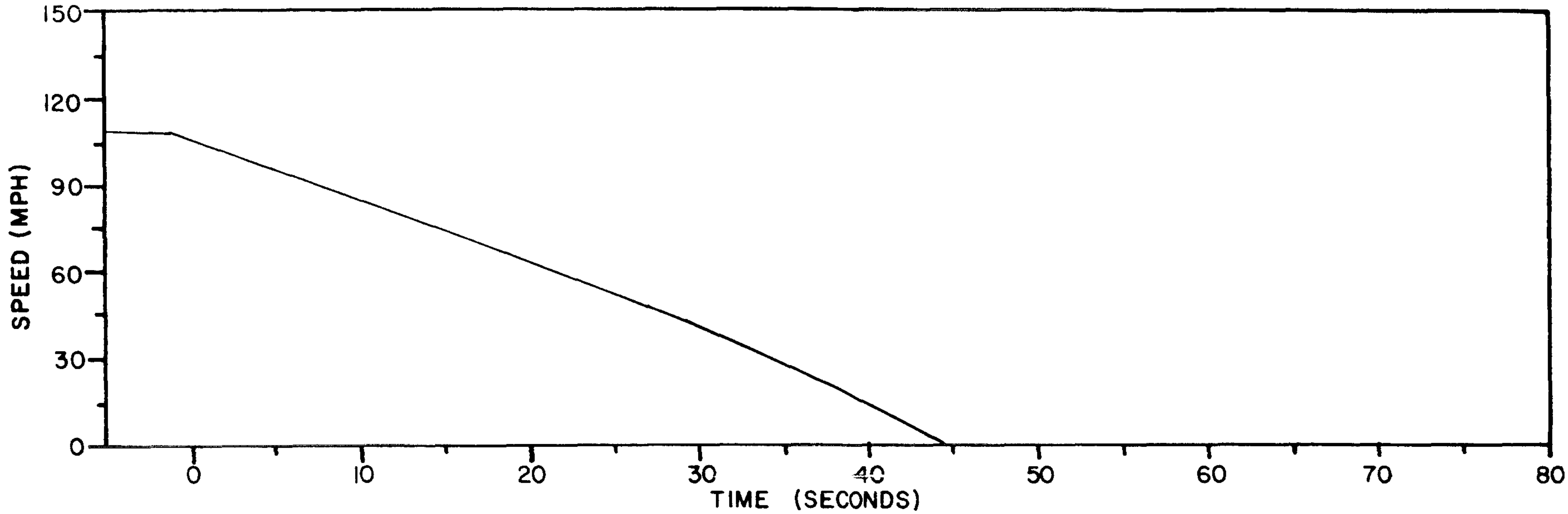

Figure B-11. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121113

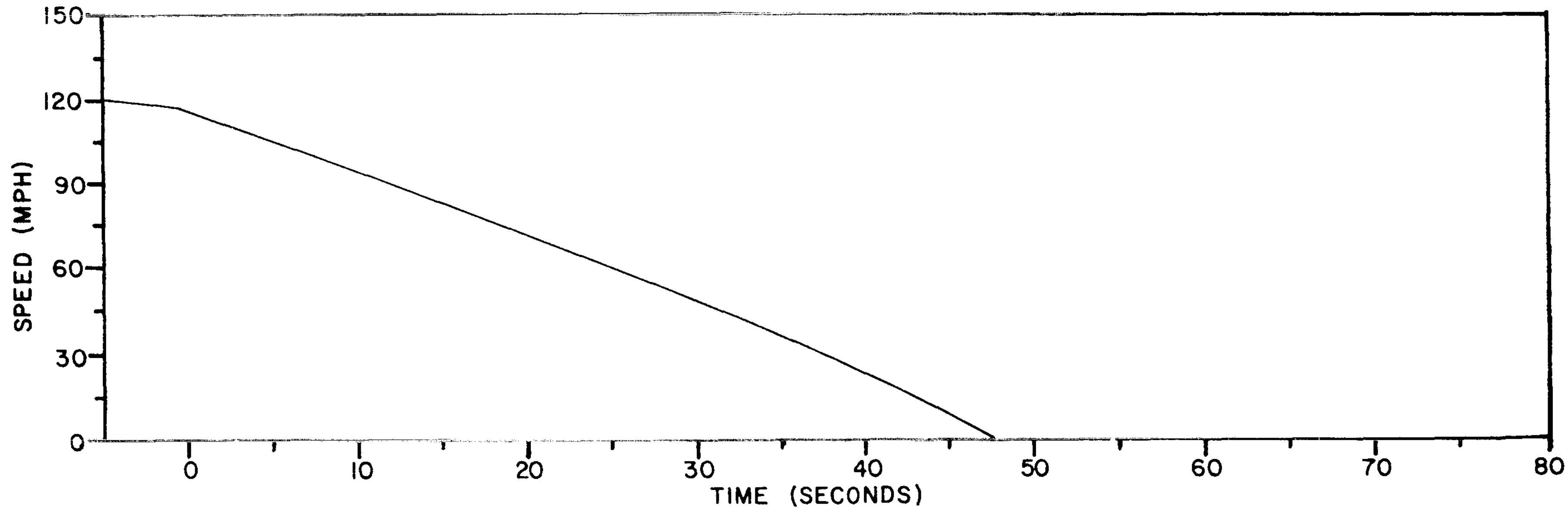

Figure B-12. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121105

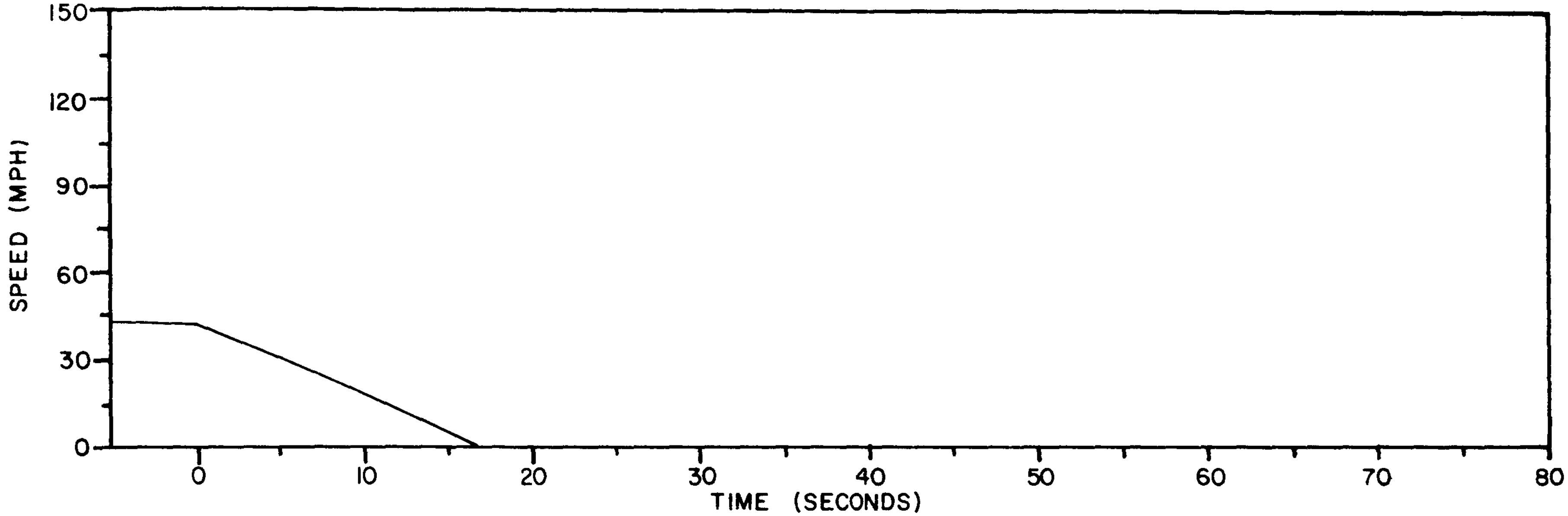

Figure B-13. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121405

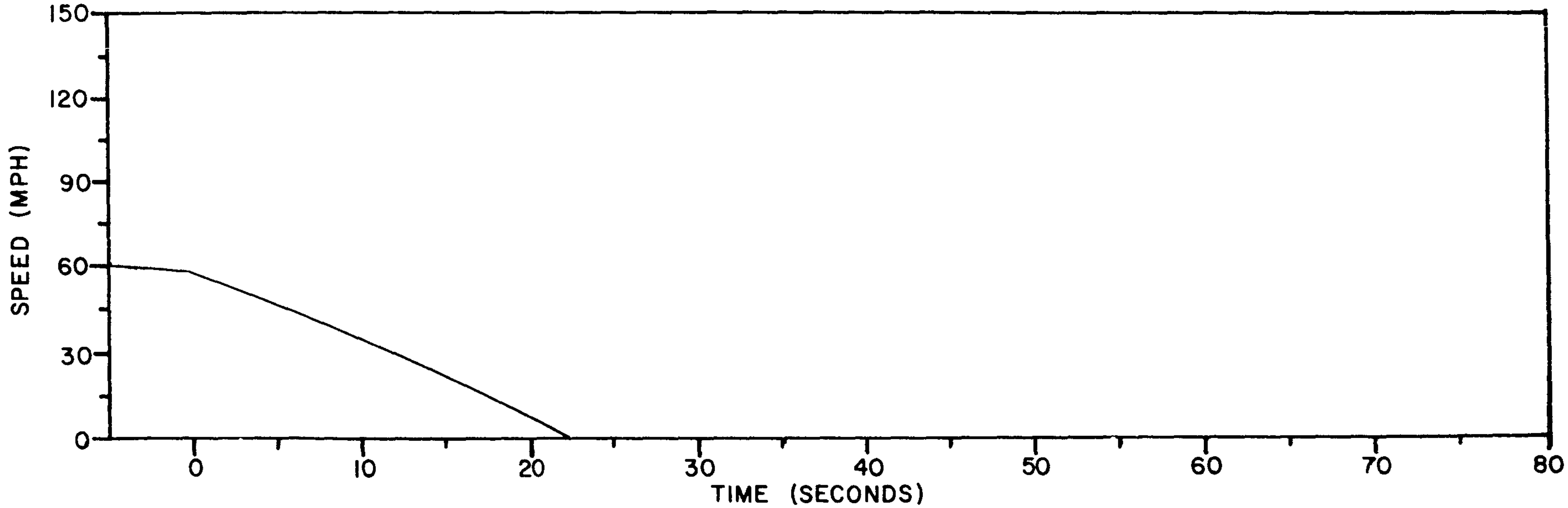

Figure B-14. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121403

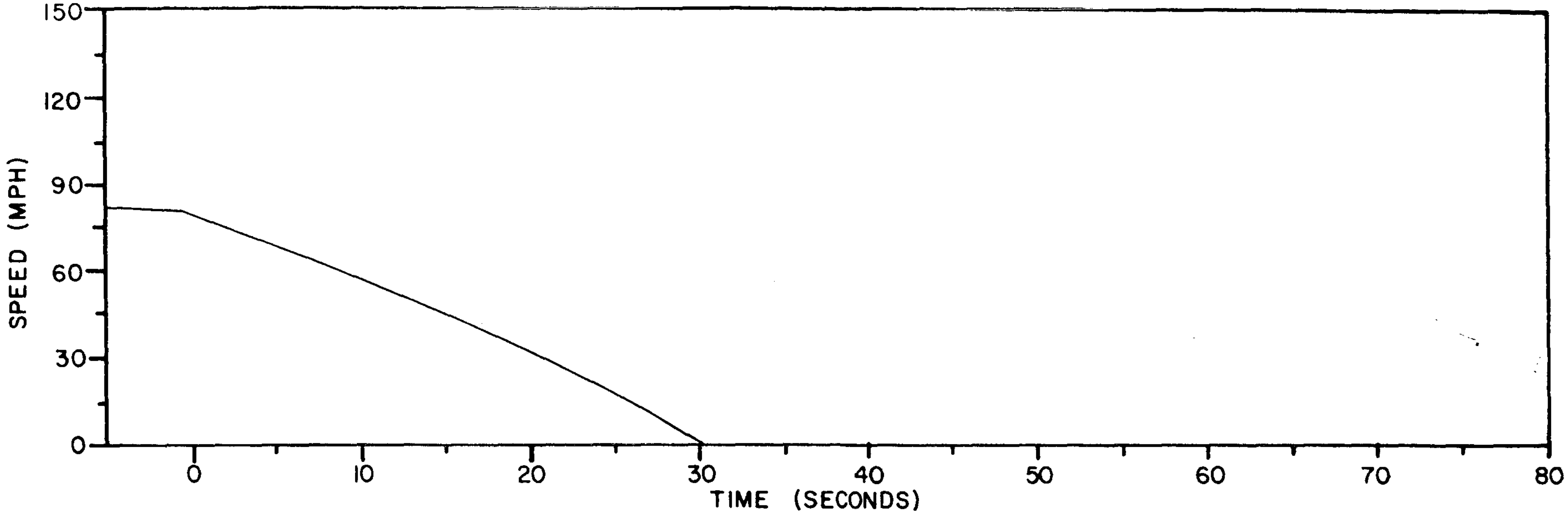

Figure B-15. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121401

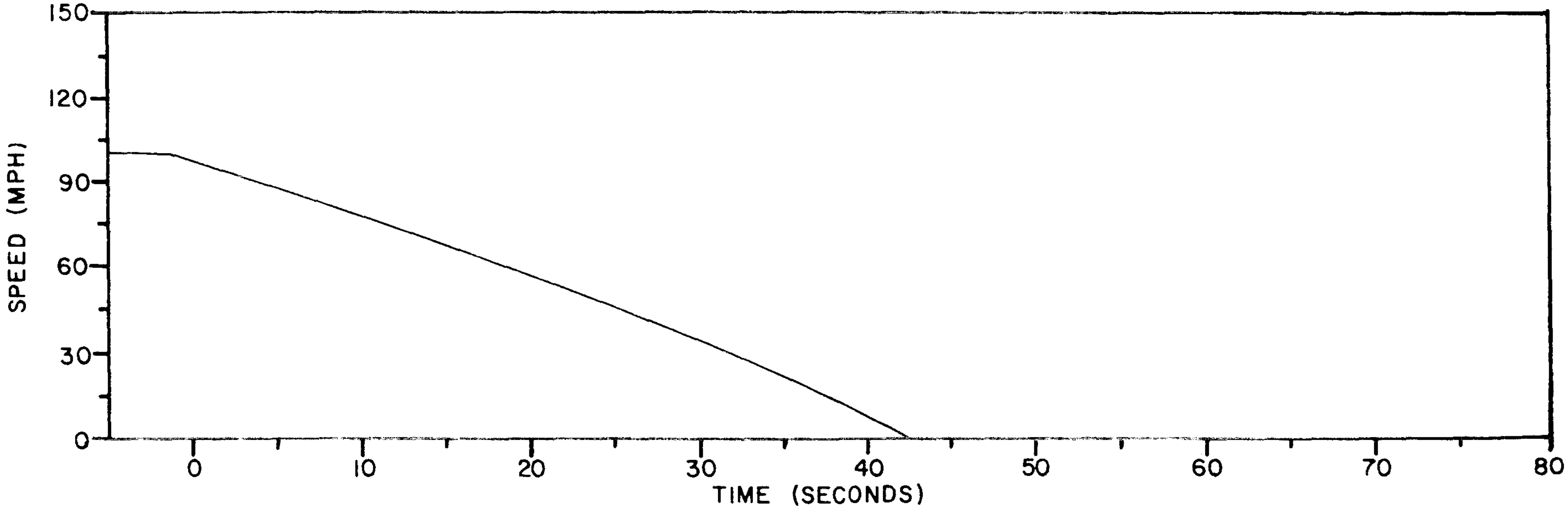

Figure B-16. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121702

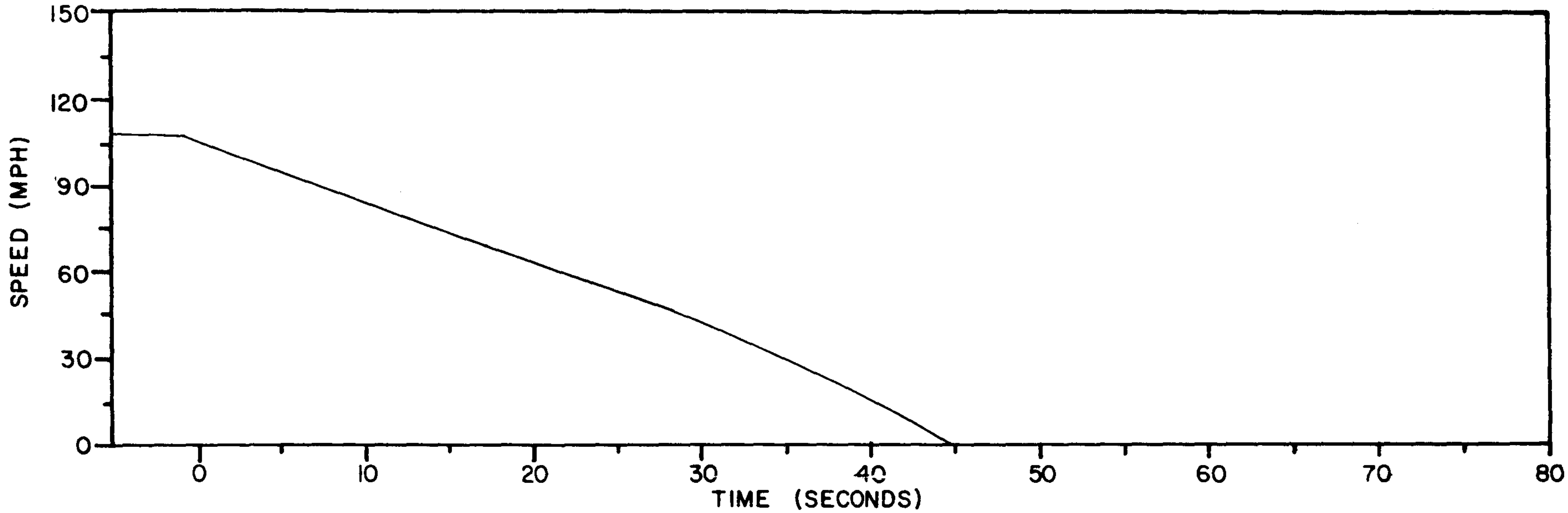

Figure B-17. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121706

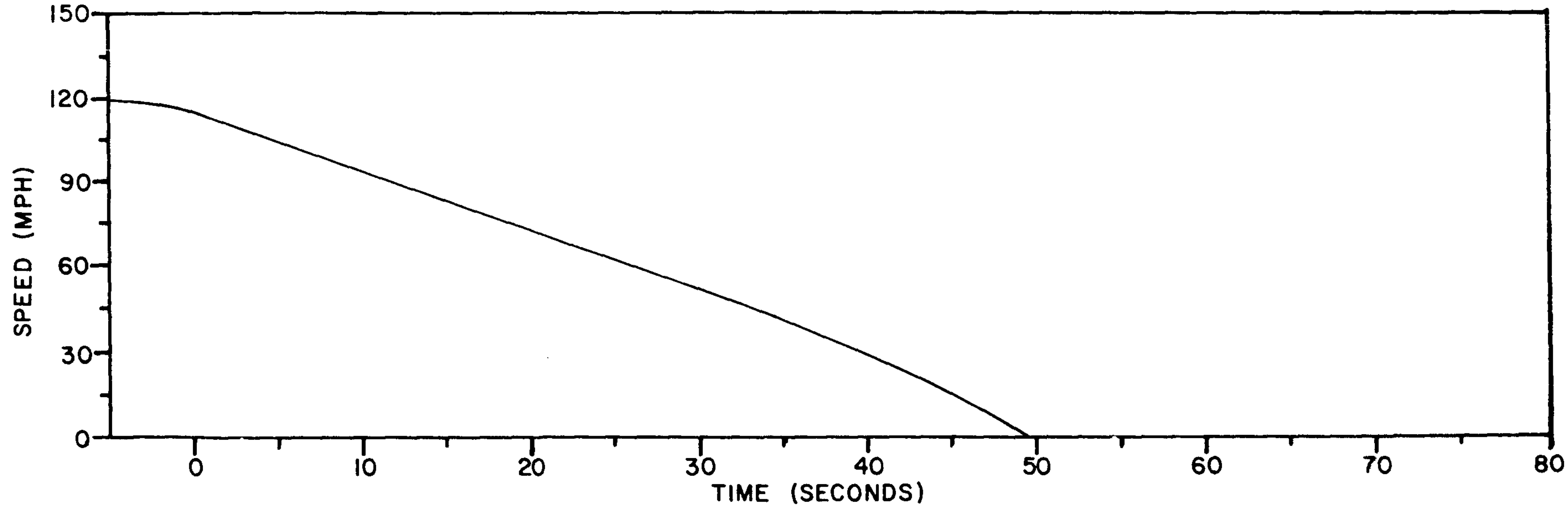

Figure B-18. Car No. 21044 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 121704

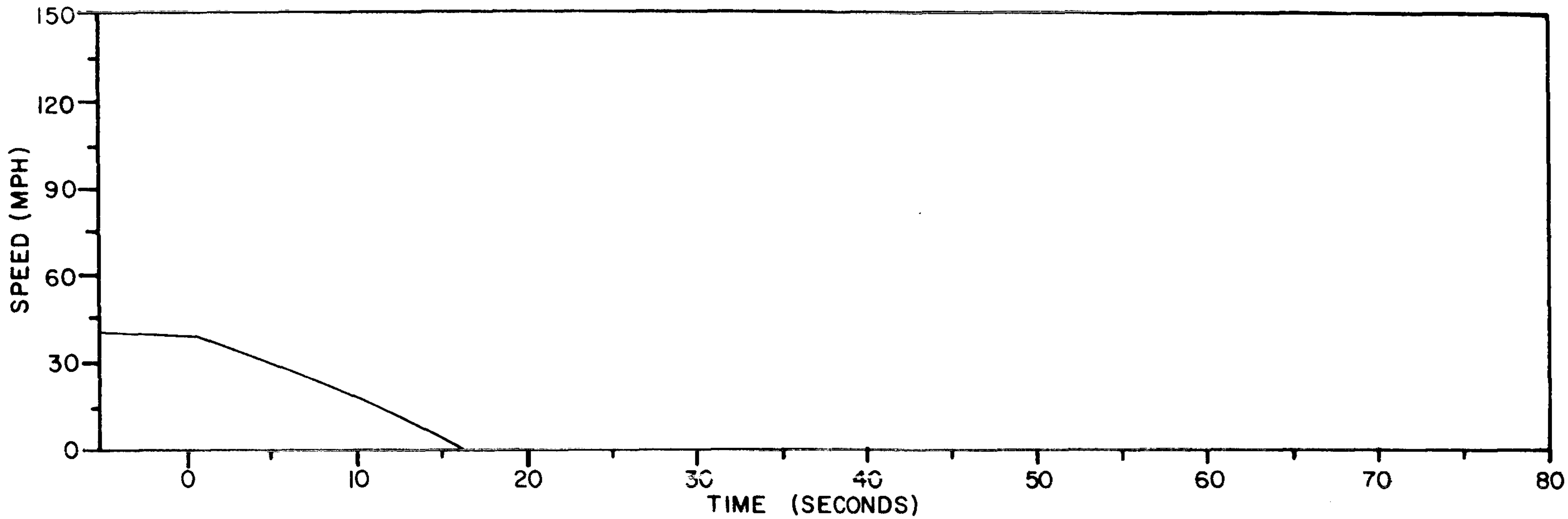

Figure B-19. Car No. 21063 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 010803

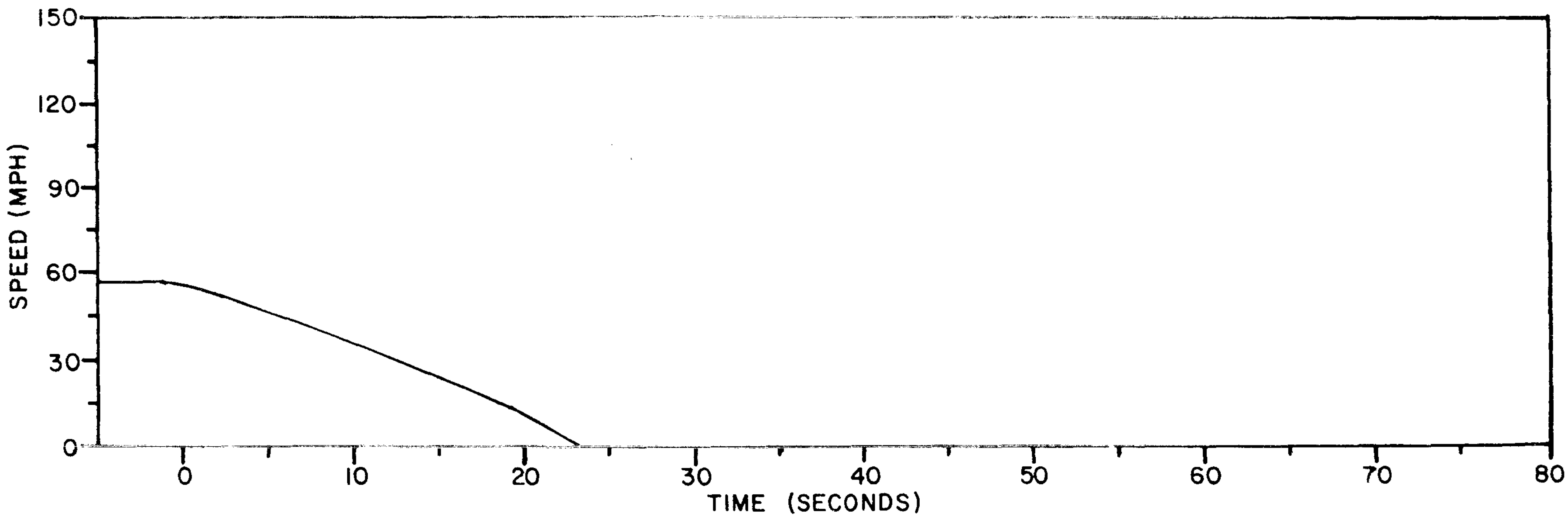

Figure B-20. Car No. 21063 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 010705

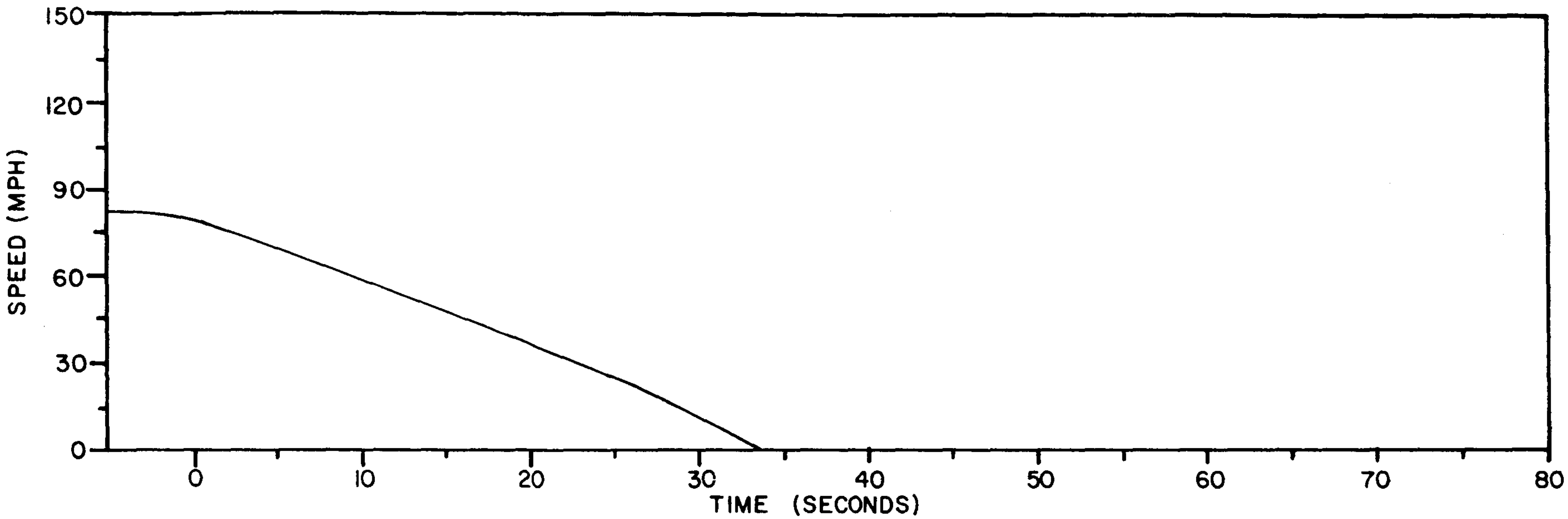

Figure B-21. Car No. 21063 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 010701

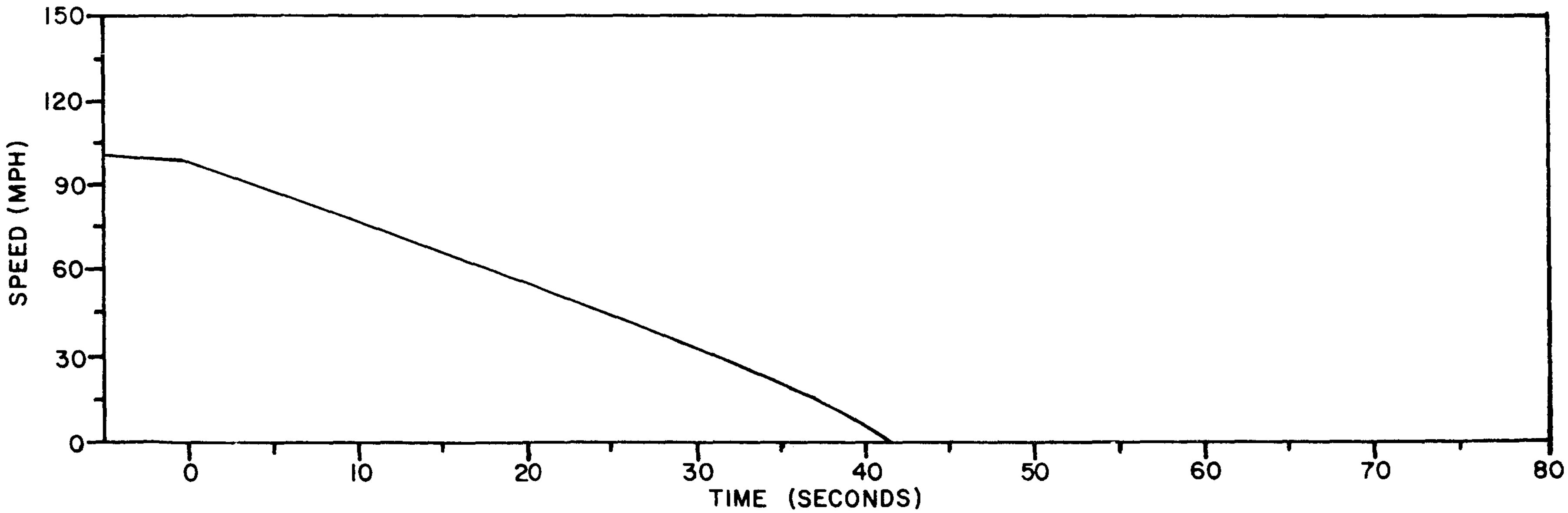

Figure B-22. Car No. 21063 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 010703

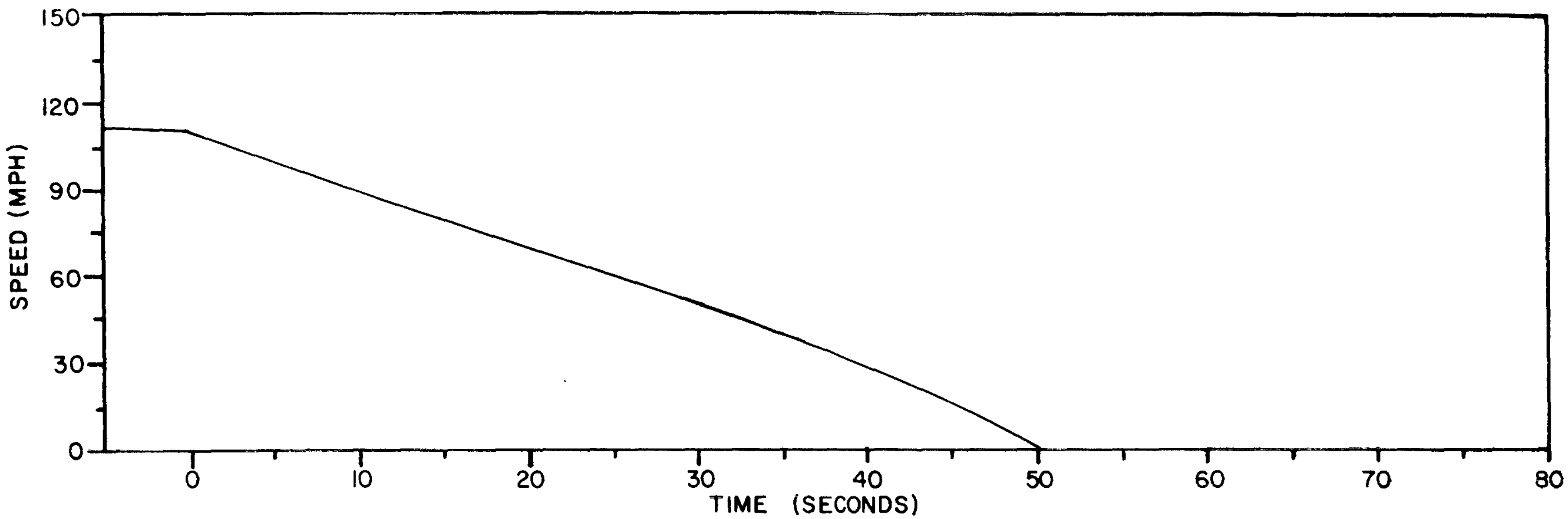

Figure B-23. Car No. 21063 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 010808

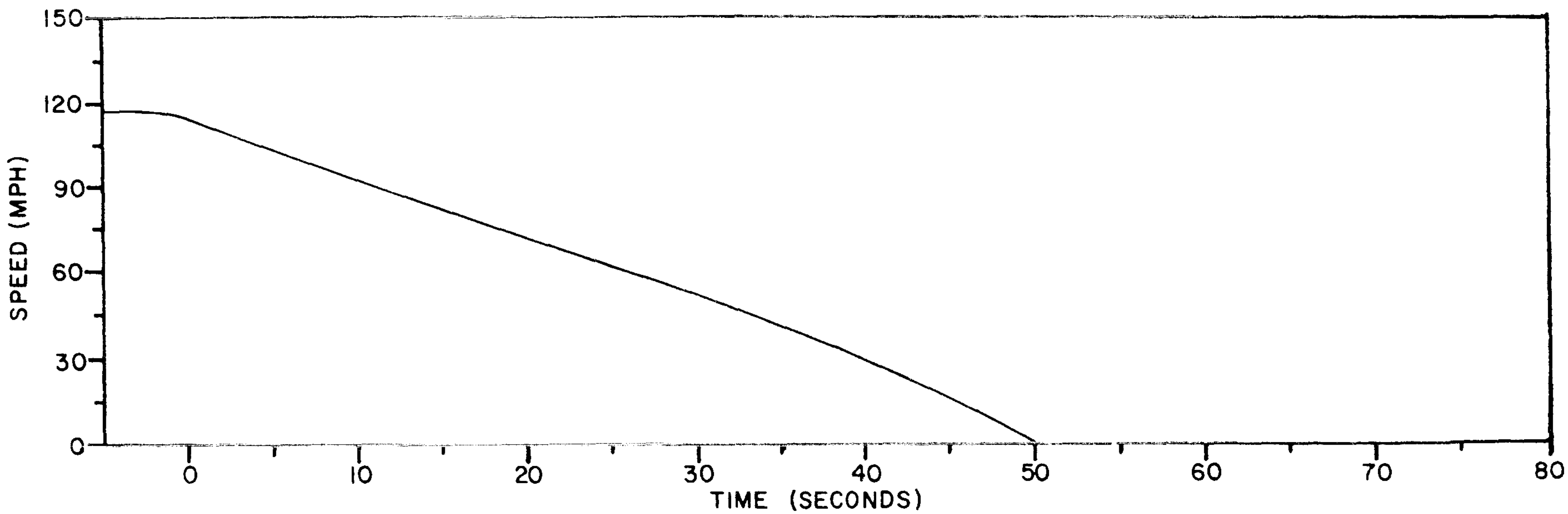

Figure B-24. Car No. 21063 - Full Service Braking (50/50 Disc/Tread Ratio) - Run No. 010809

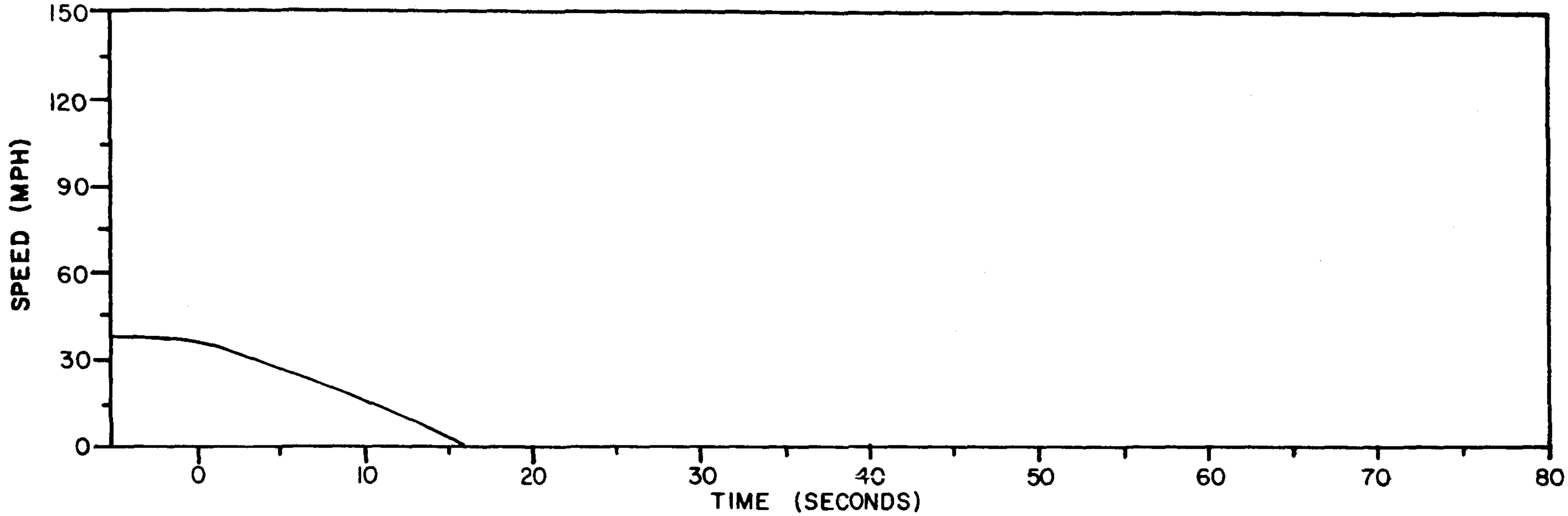

Figure B-25. Car No. 21063 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 011012

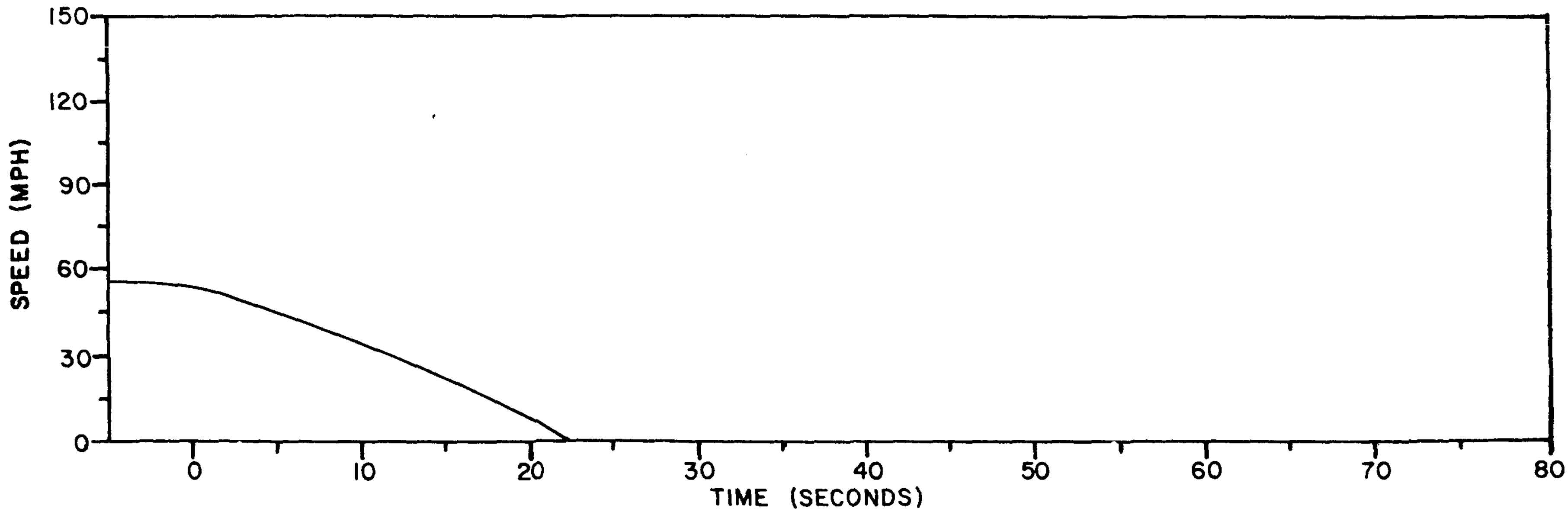

Figure B-26. Car No 21063 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 011010

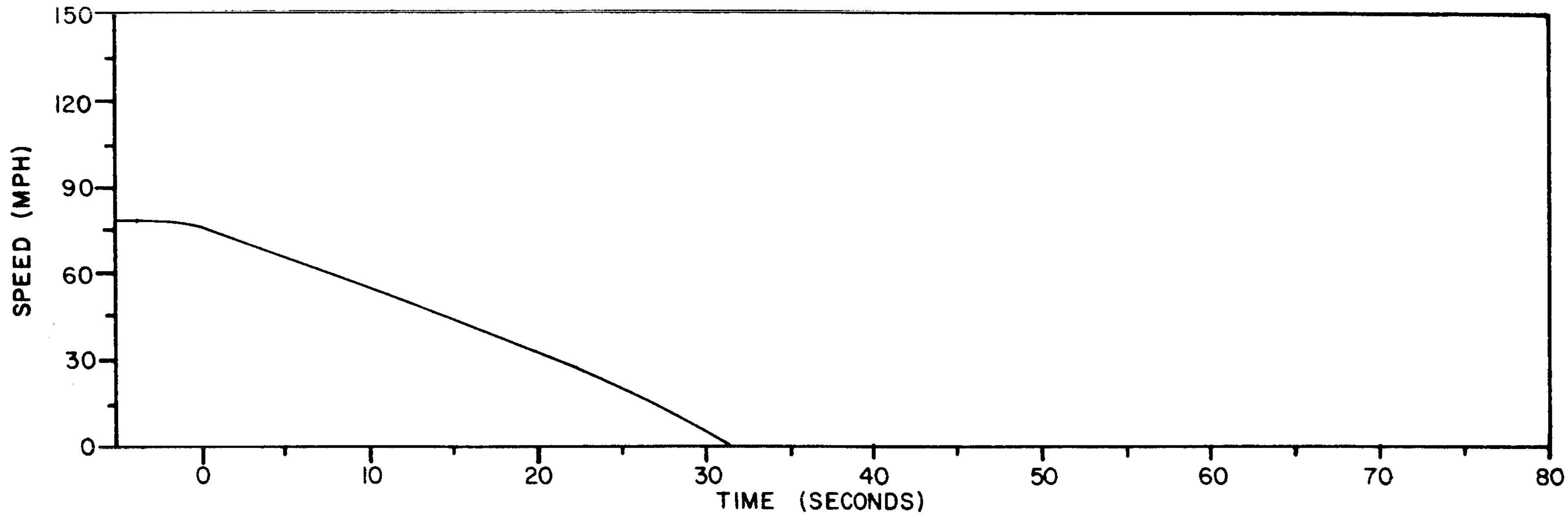

Figure B-27. Car No 21063 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 011008

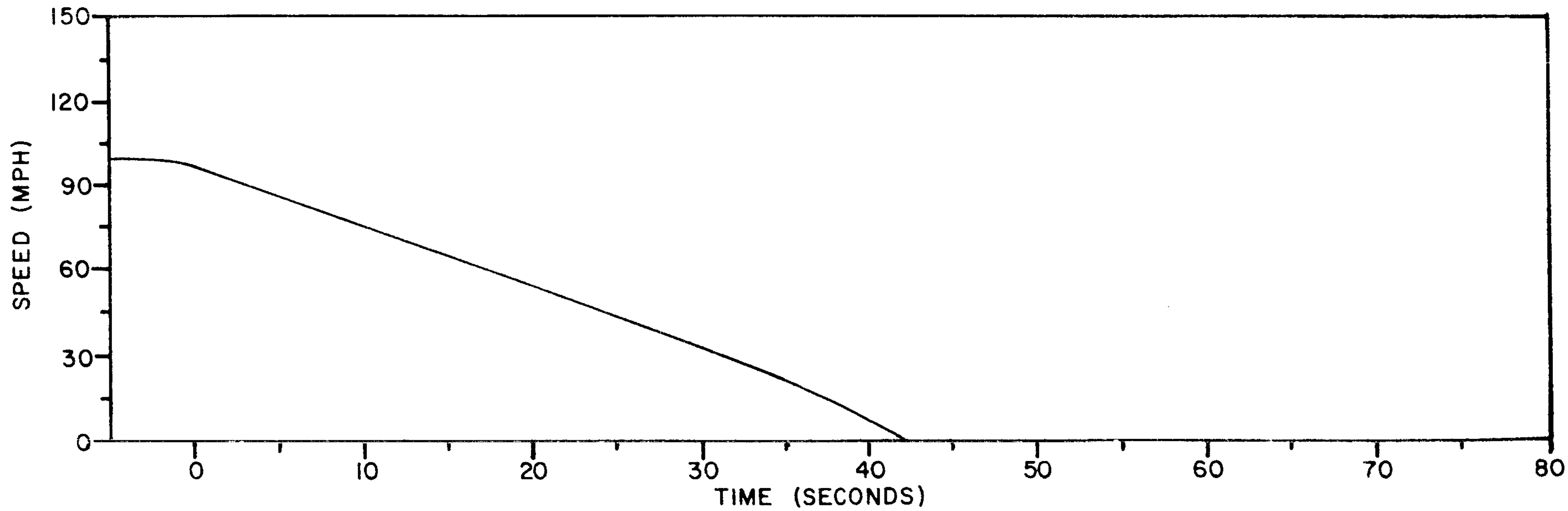

Figure B-28. Car No. 21063 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 011009

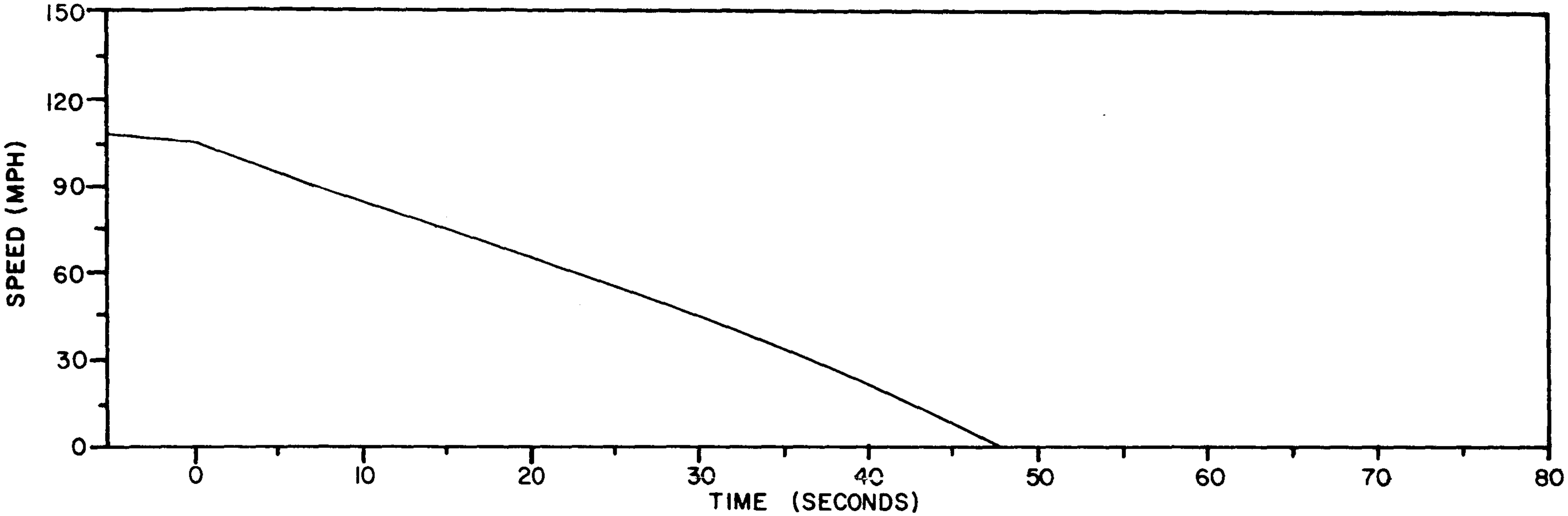

Figure B-29. Car No. 21063 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 011011

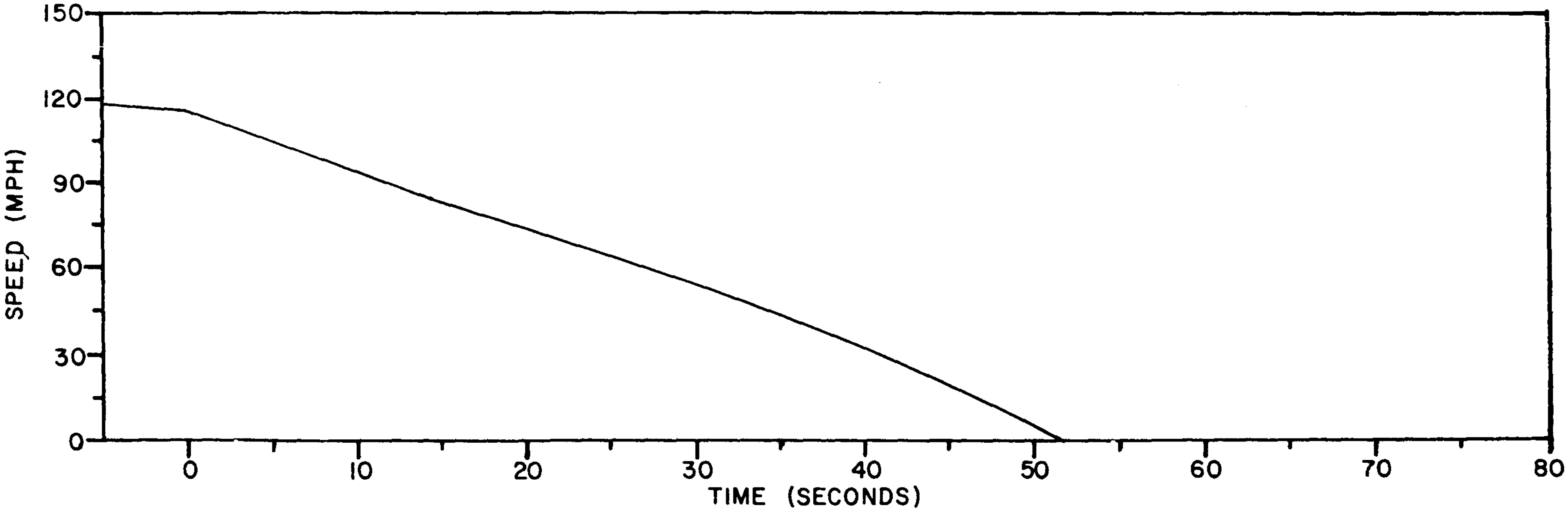

Figure B-30. Car No. 21063 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 011013

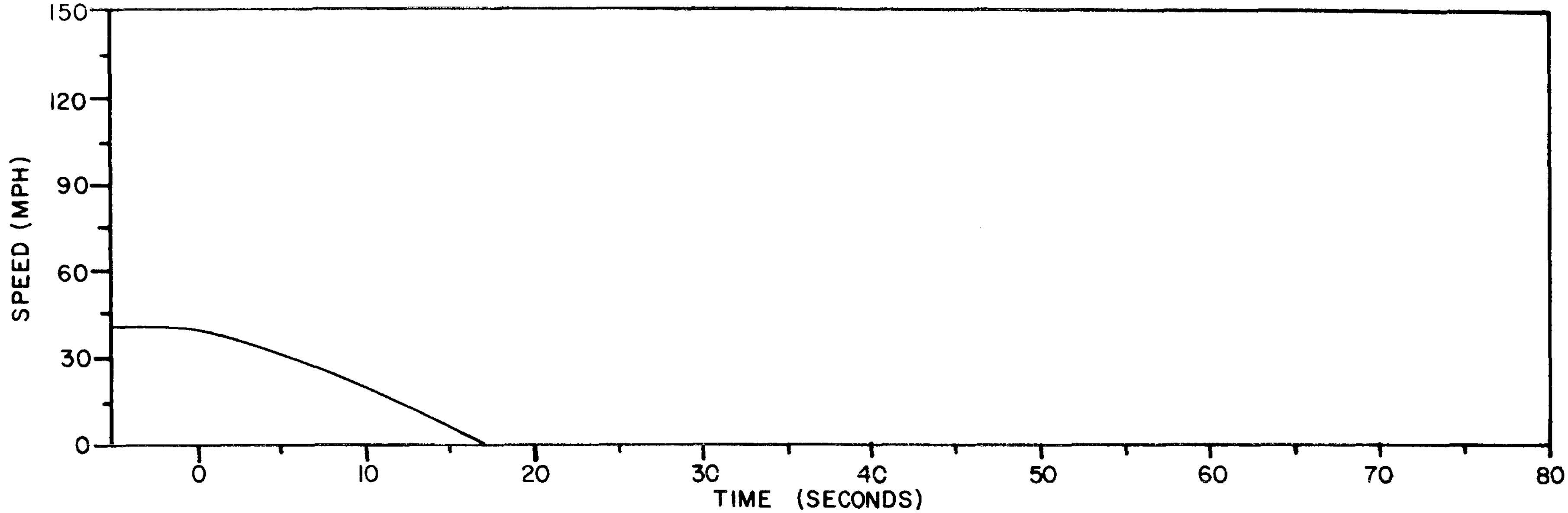

Figure B-31. Car No. 21087 - Full Service Braking (70/30 Disc/Tread Ratio) - Run No. 012204

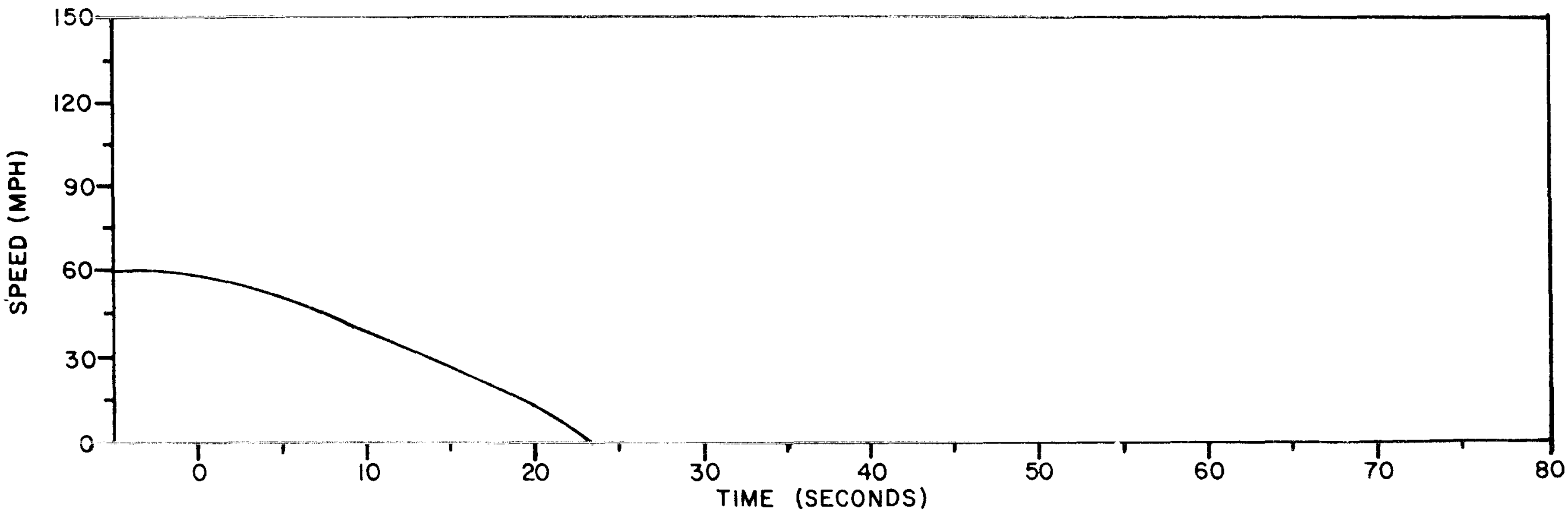

Figure B-32. Car No. 21087 - Full Service Braking (70/30 Disc/Tread Ratio) - Run No. 012203

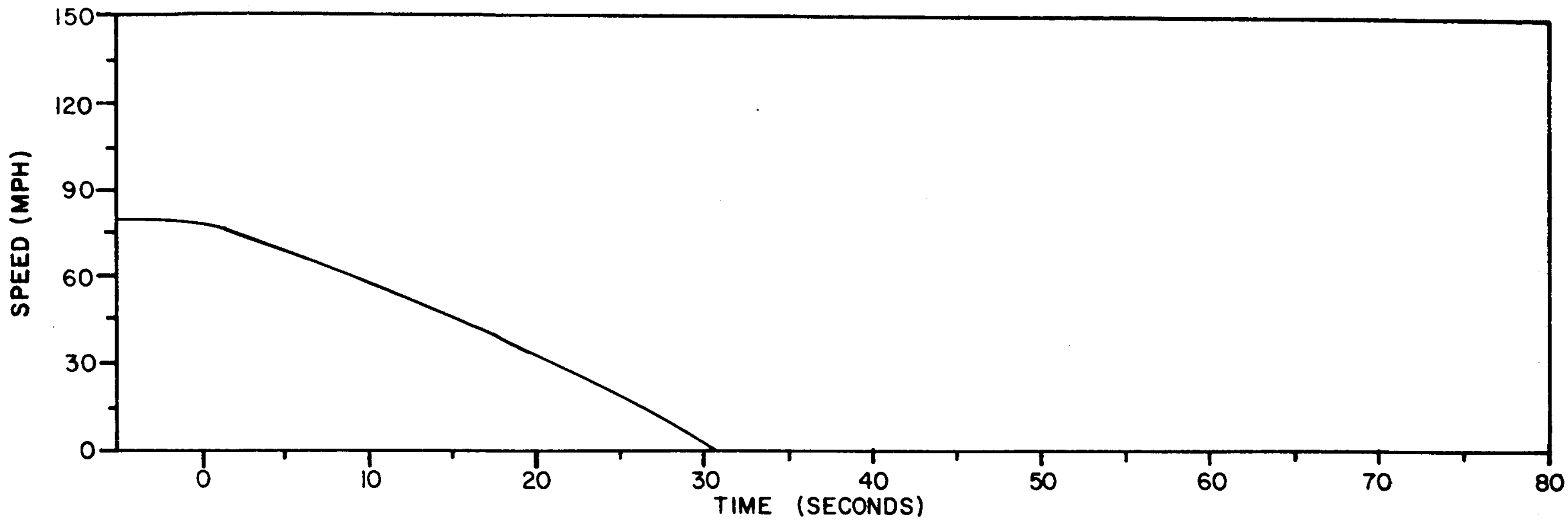

Figure B-33. Car No. 21087 - Full Service Braking (70/30 Disc/Tread Ratio) - Run.No. 012206

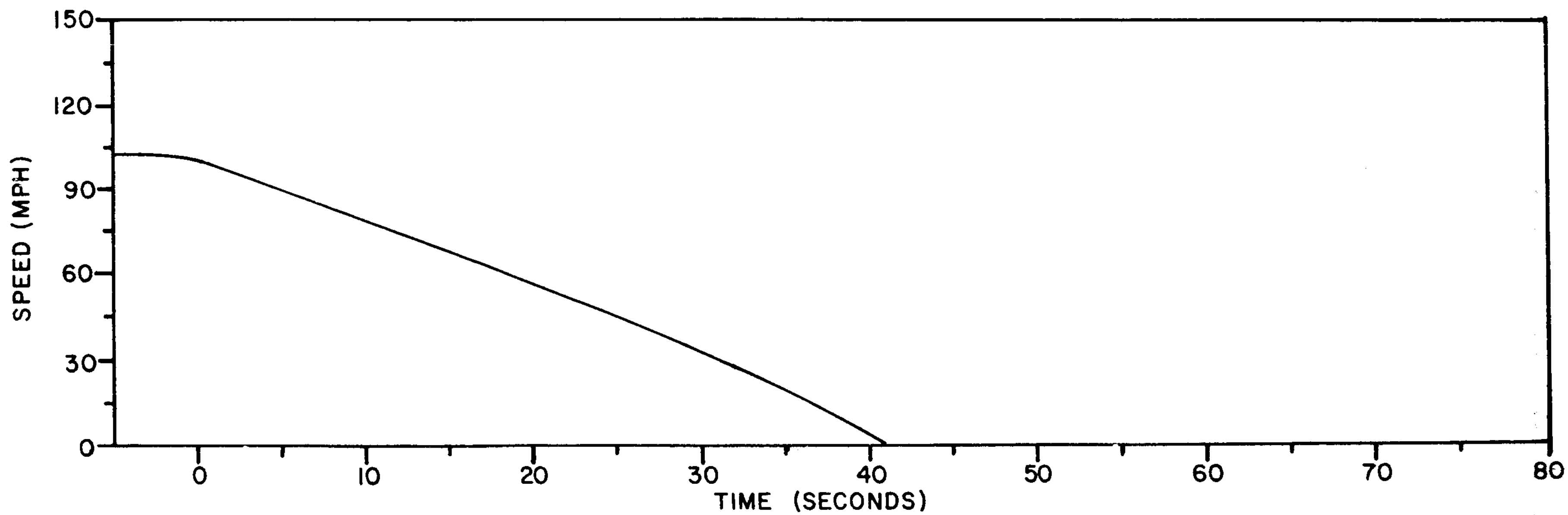

Figure B-34. Car No. 21087 - Full Service Braking (70/30 Disc/Tread Ratio) - Run No. 012207

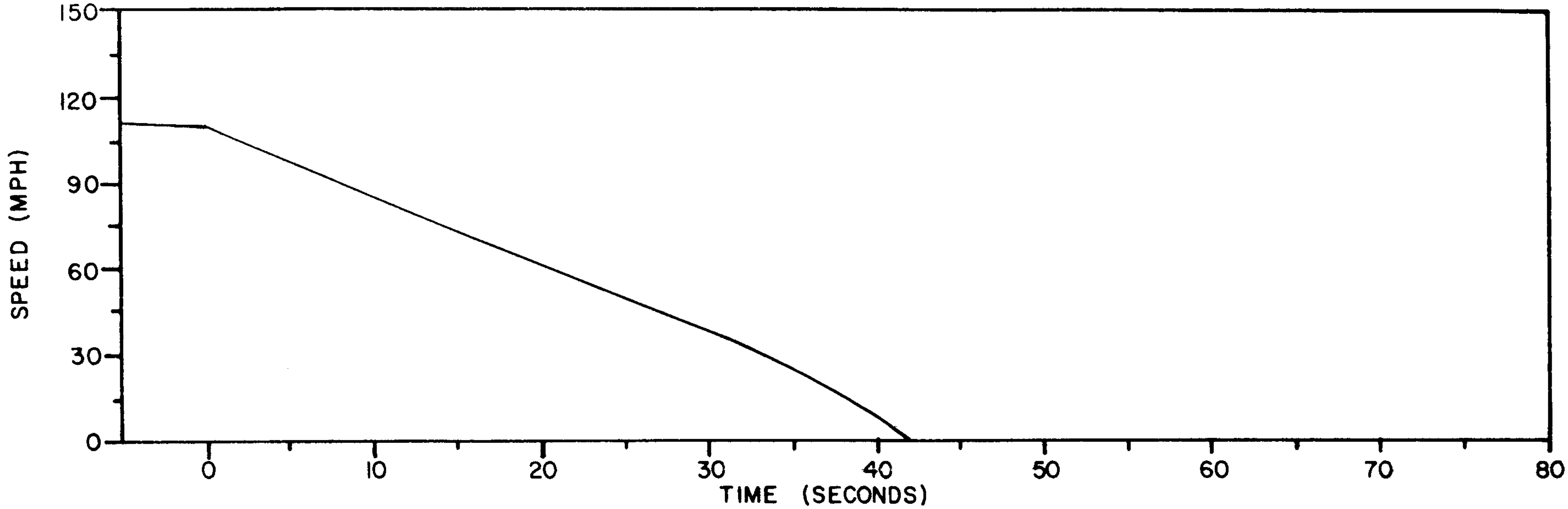

Figure B-35. Car No. 21087 - Full Service Braking (70/30 Disc/Tread Ratio)- Run No. 012302

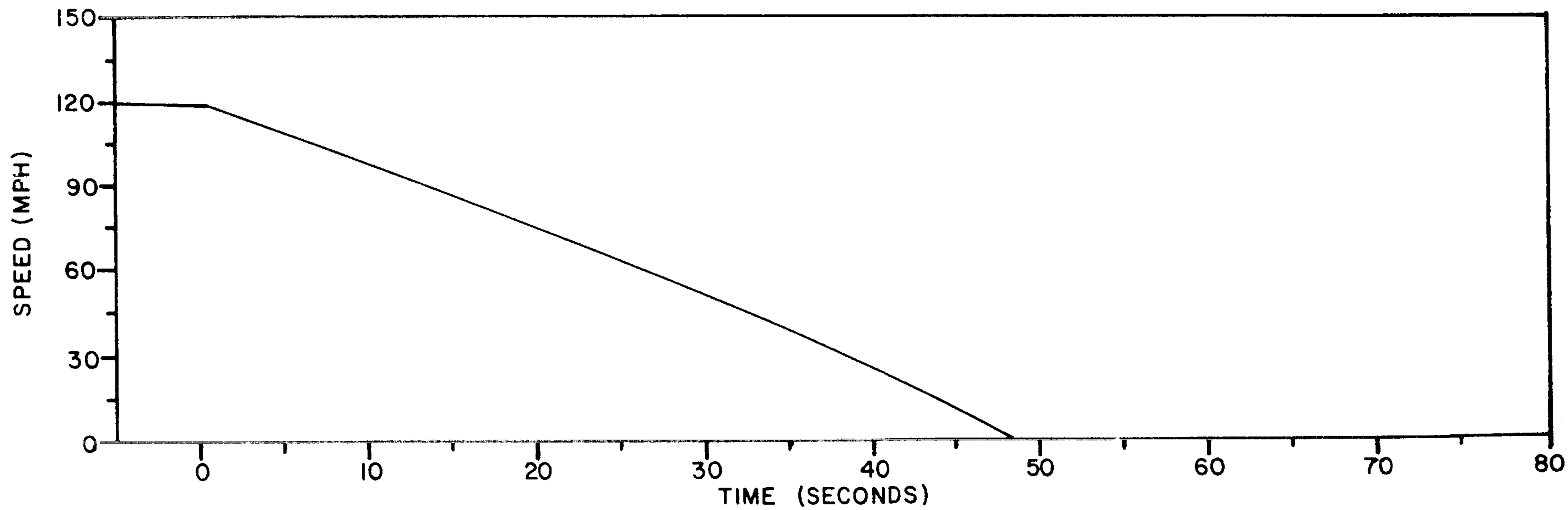

Figure B-36. Car No. 21087 - Full Service Braking (70/30 Disc/Tread Ratio) - Run No. 012205

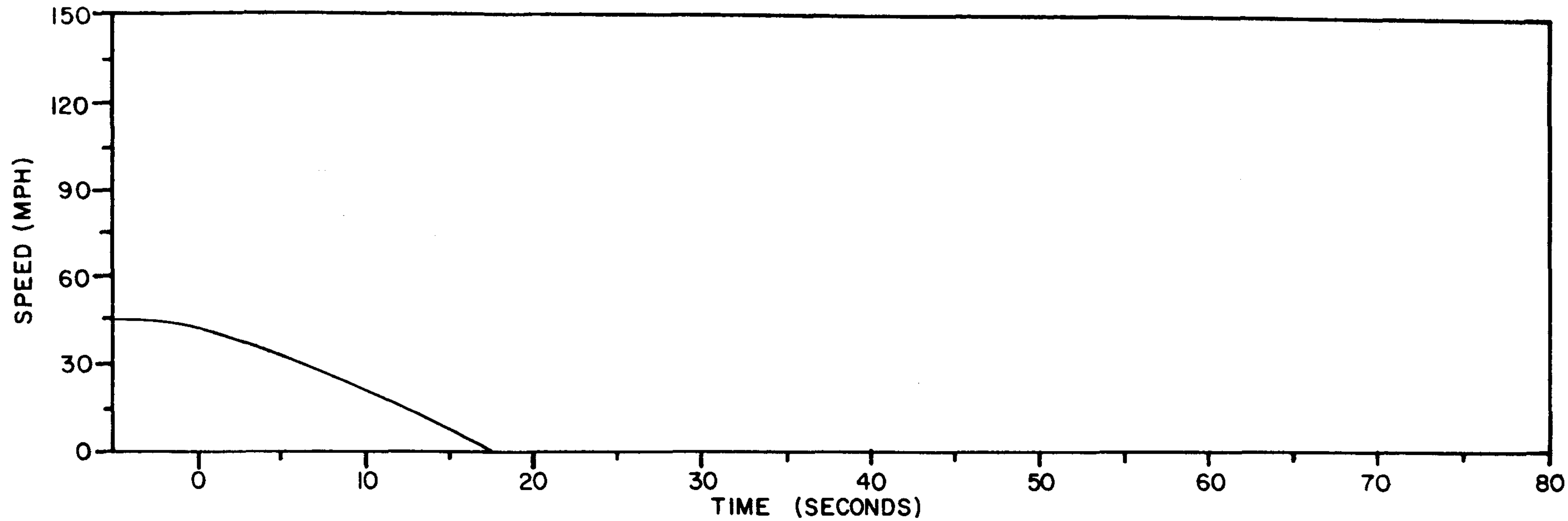

Figure B-37. Car No. 21087 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 013106

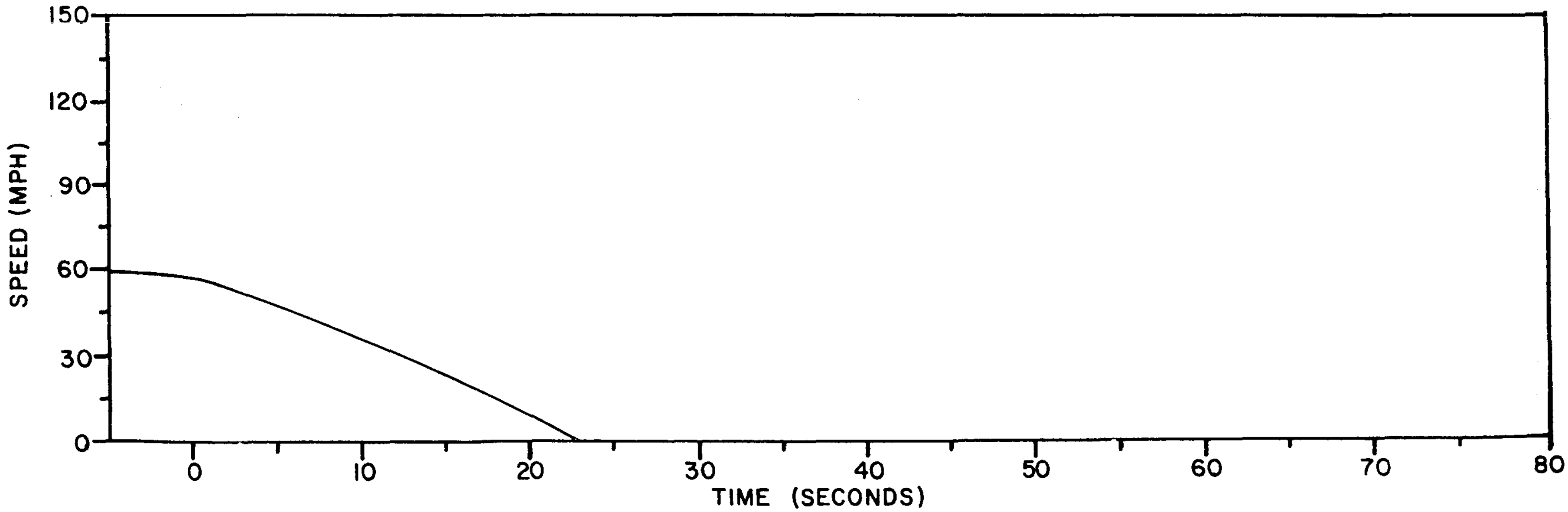

Figure B-38. Car No. 21087 - Full Service Braking (60/40 Disc/Treat Ratio) - Run No. 013108

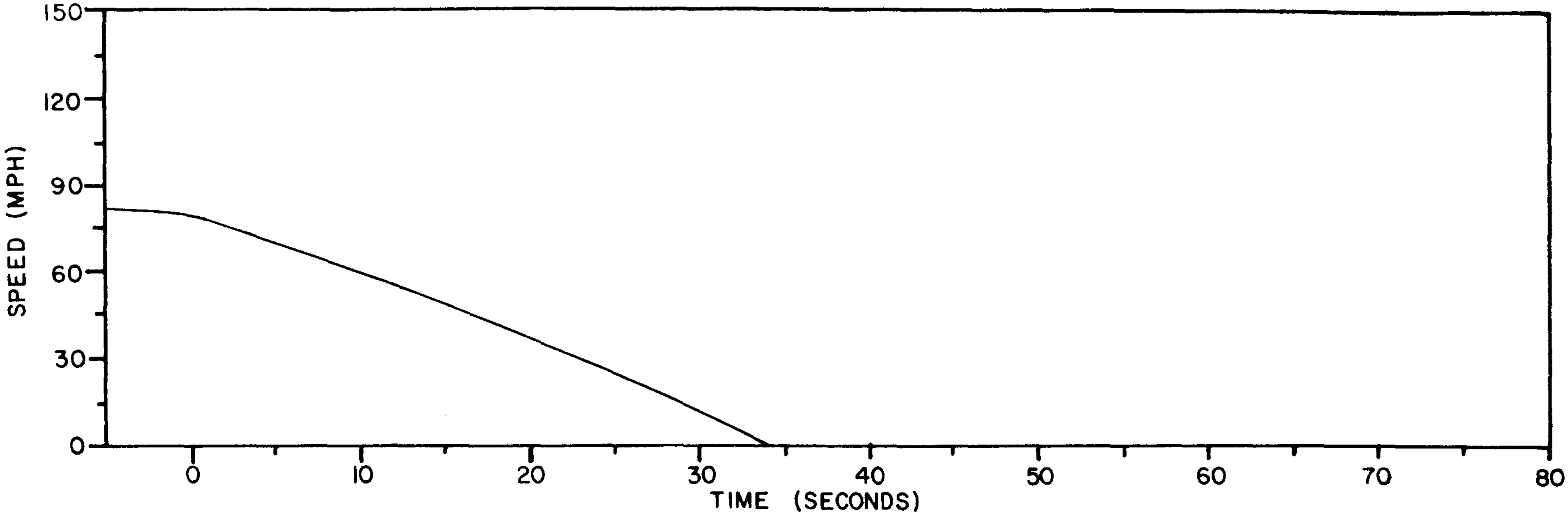

Figure B-39. Car No. 21087 - Full Service Braking (60/40 Disc/Tread Ratio)-
Run No. 013104

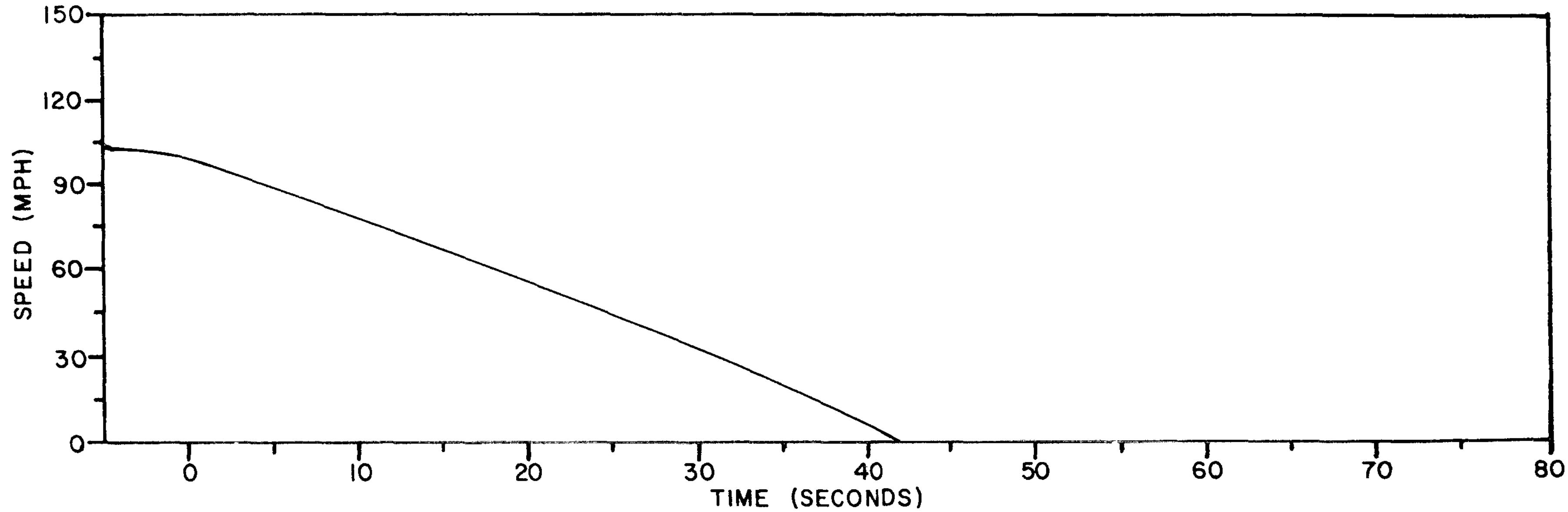

Figure B-40. Car No. 21087 - Full Service Braking (60/40 Disc/Tread Ratio) -
Run No. 013109

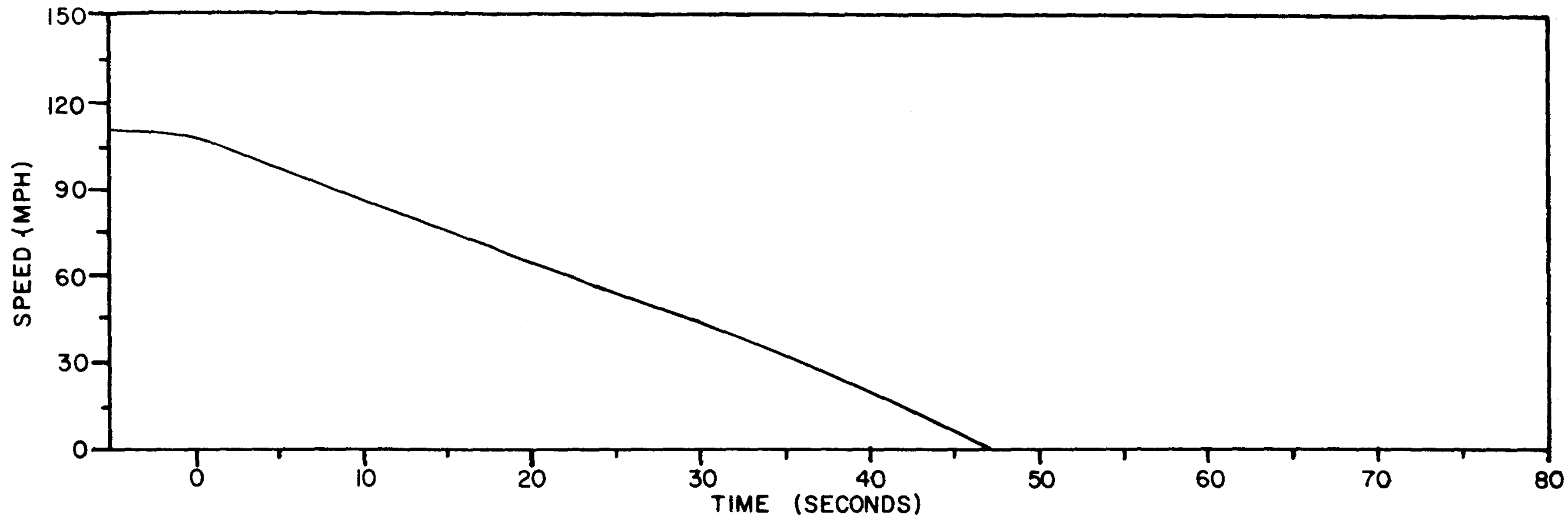

Figure B-41. Car No. 21087 - Full Service Braking (60/40 Disc/Tread Ratio) - Run No. 013107

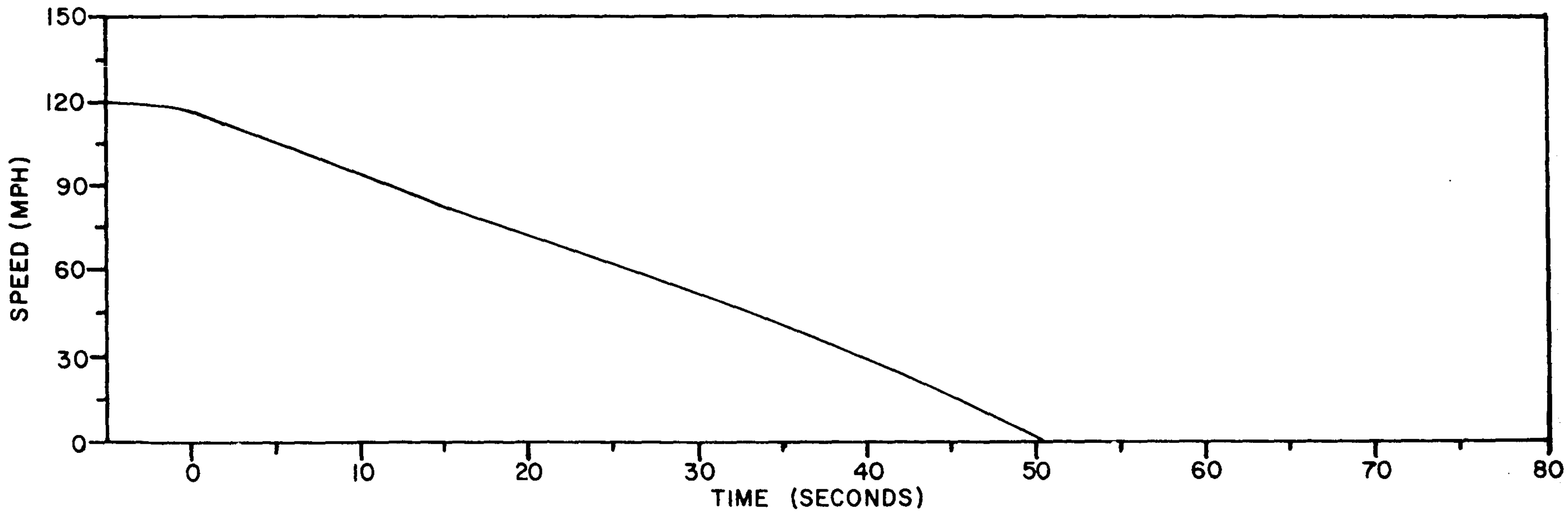

Figure B-42. Car No. 21087 - Full Service Braking (60/40 Disc/Tread Ratio) - Run Co. 013105

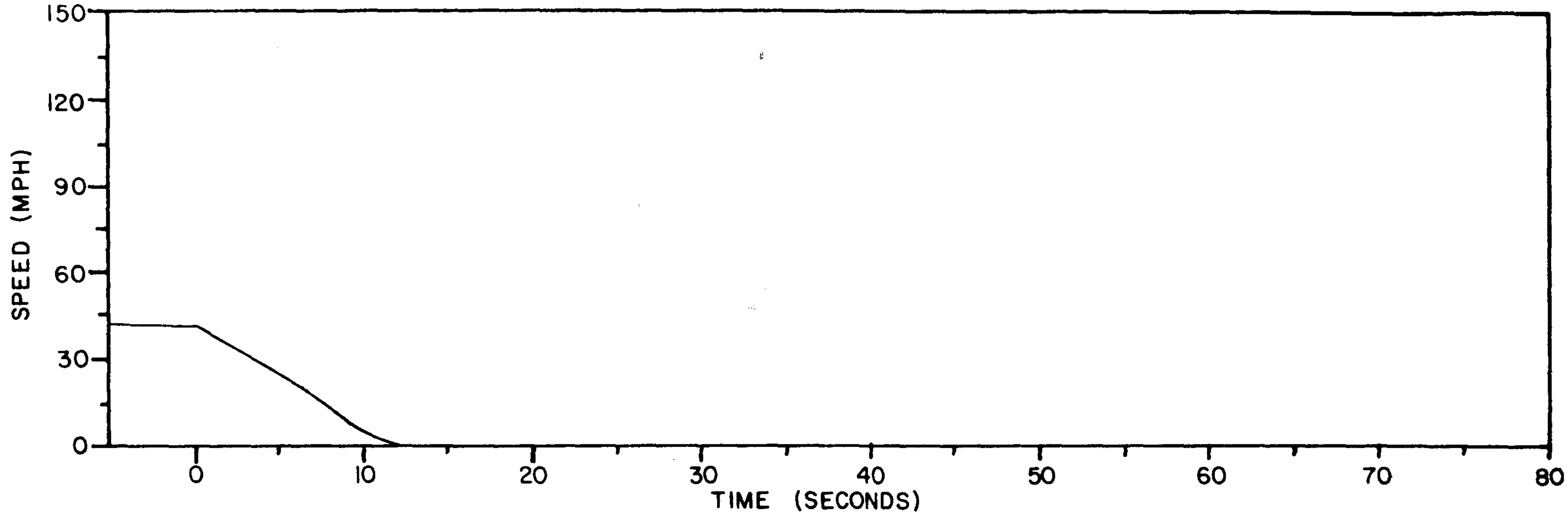

Figure B-43. Standard Car (No. 21018) Emergency Service - Run No. 112901

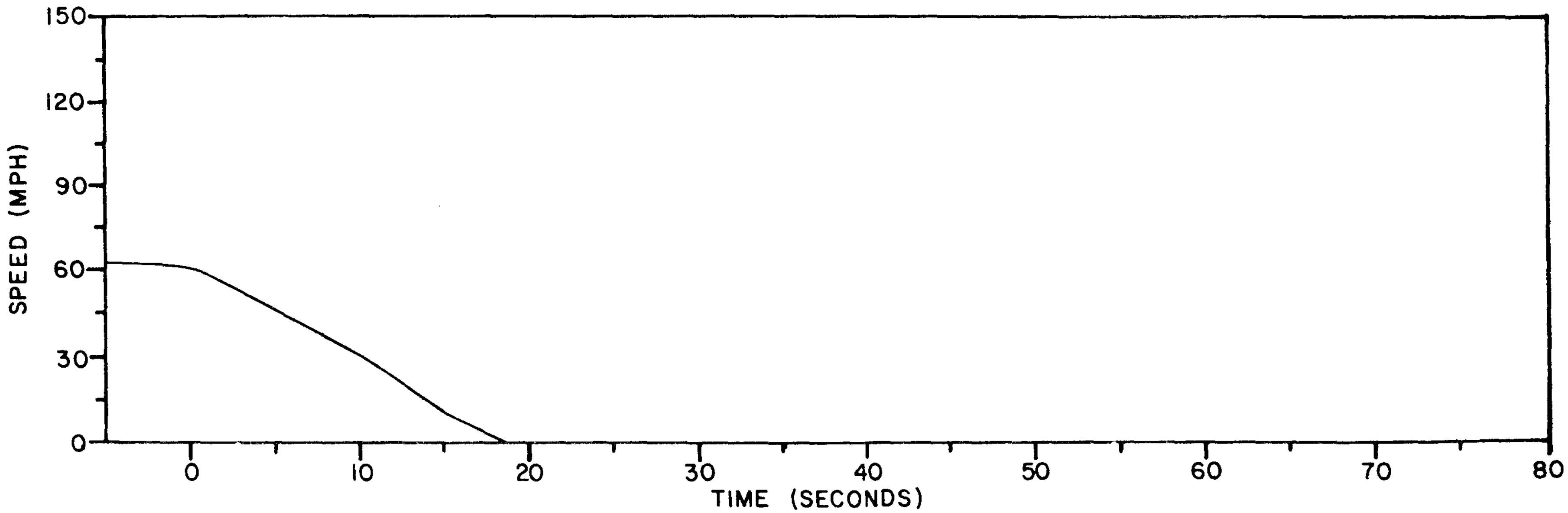

Figure B-44. Standard Car (NO. 21018) - Emergency Service - Run No. 120303

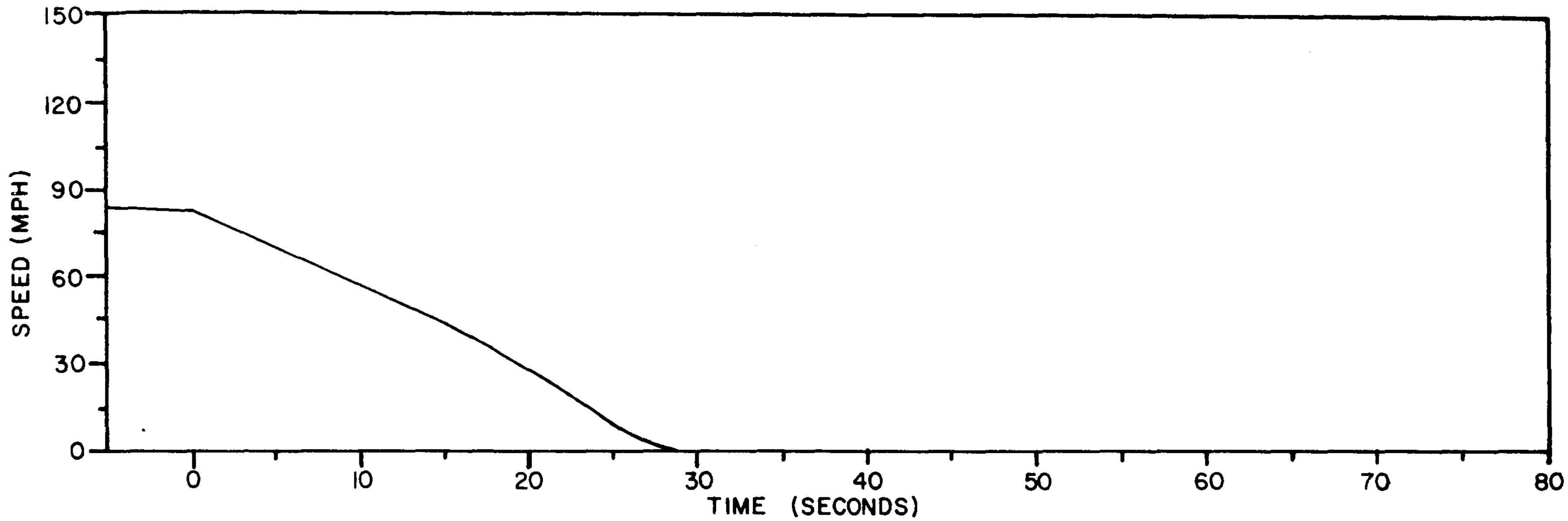

Figure B-45. Standard Car (No. 21018) - Emergency Service - Run No. 112807

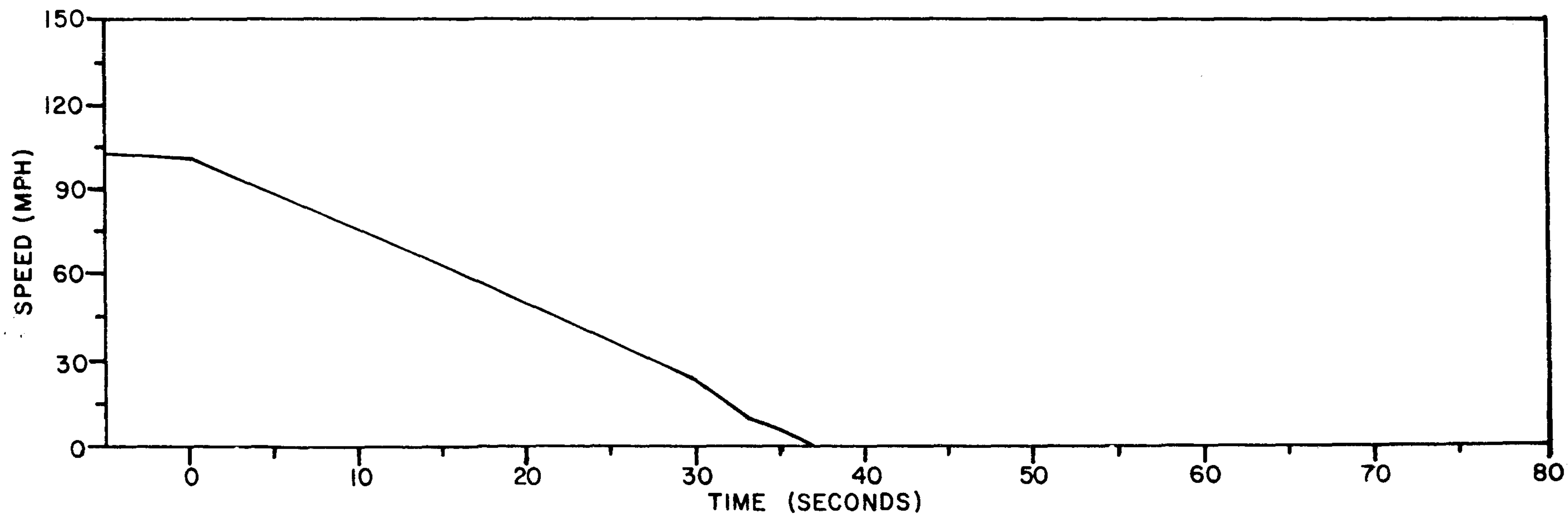

Figure B-46. Standard Car (No. 21018) - Emergency Service - Run No. 112808

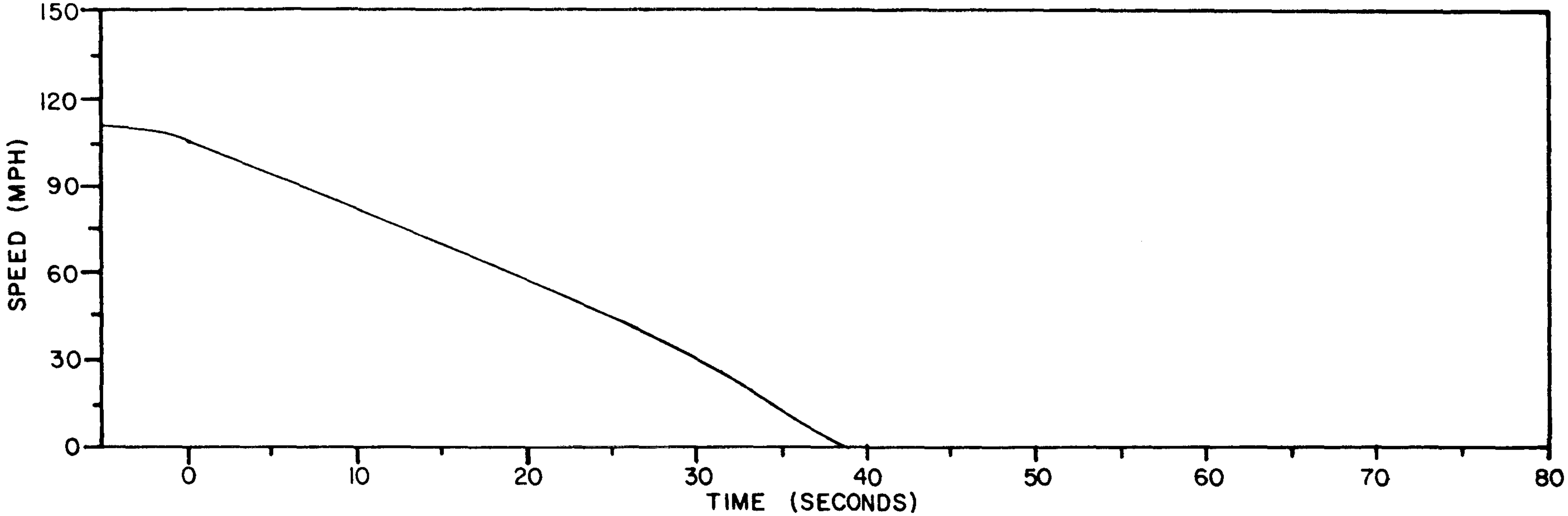

Figure B-47. Standard Car (No. 21018) - Emergency Service - Run No. 112810

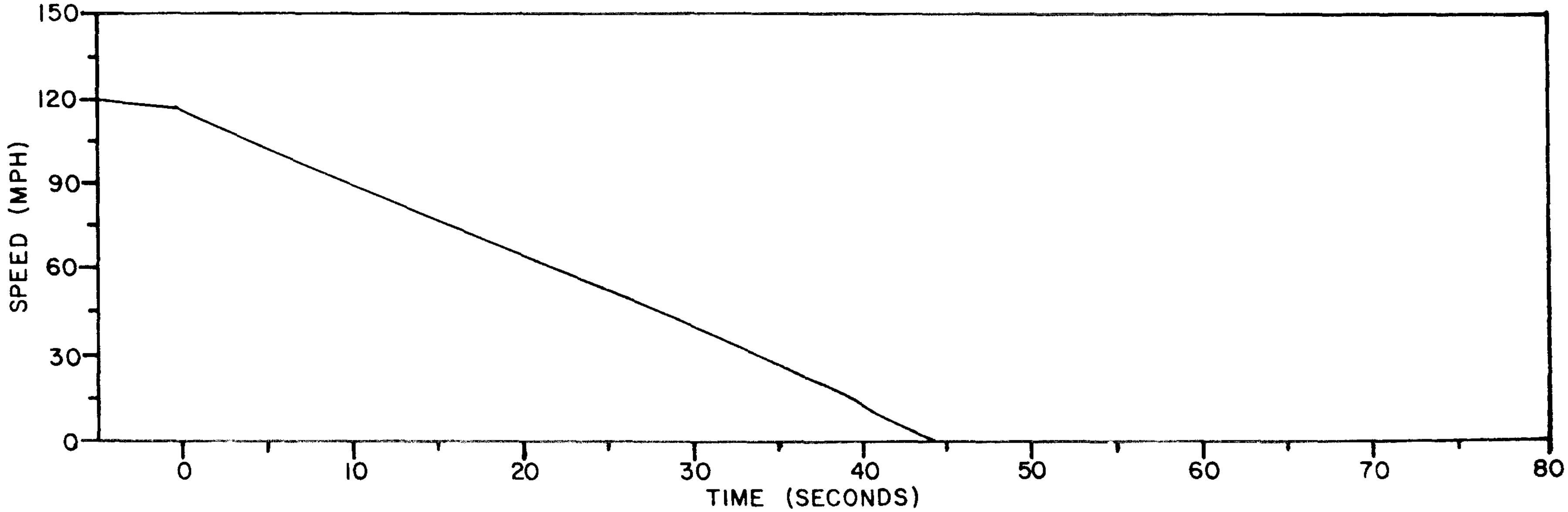

Figure B-48. Standard Car (No. 21018) - Emergency Service - Run No. 112902

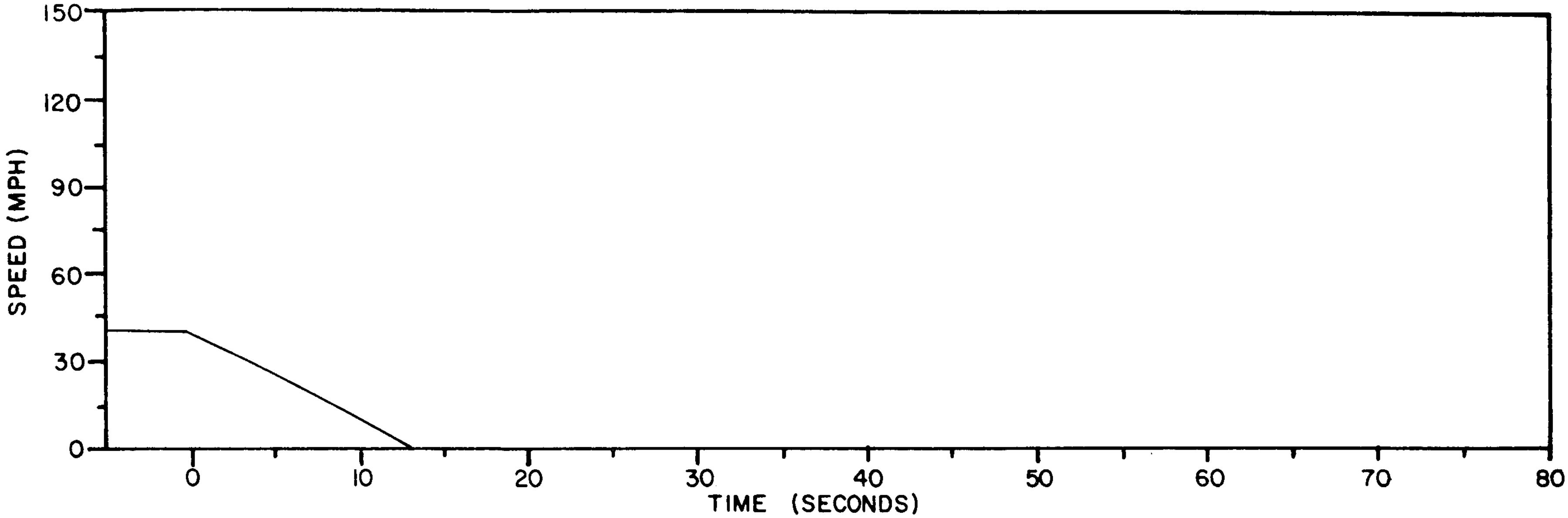

Figure B-49. Car No. 21044 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 121205

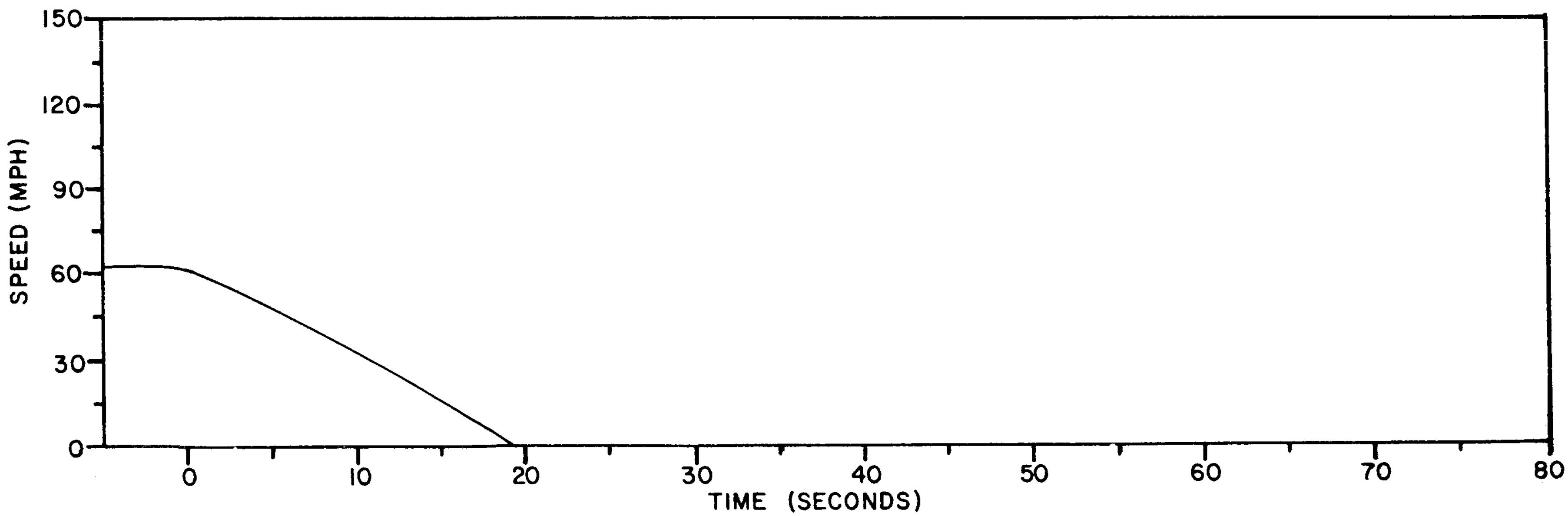

Figure B-50. Car No. 21044 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 121203

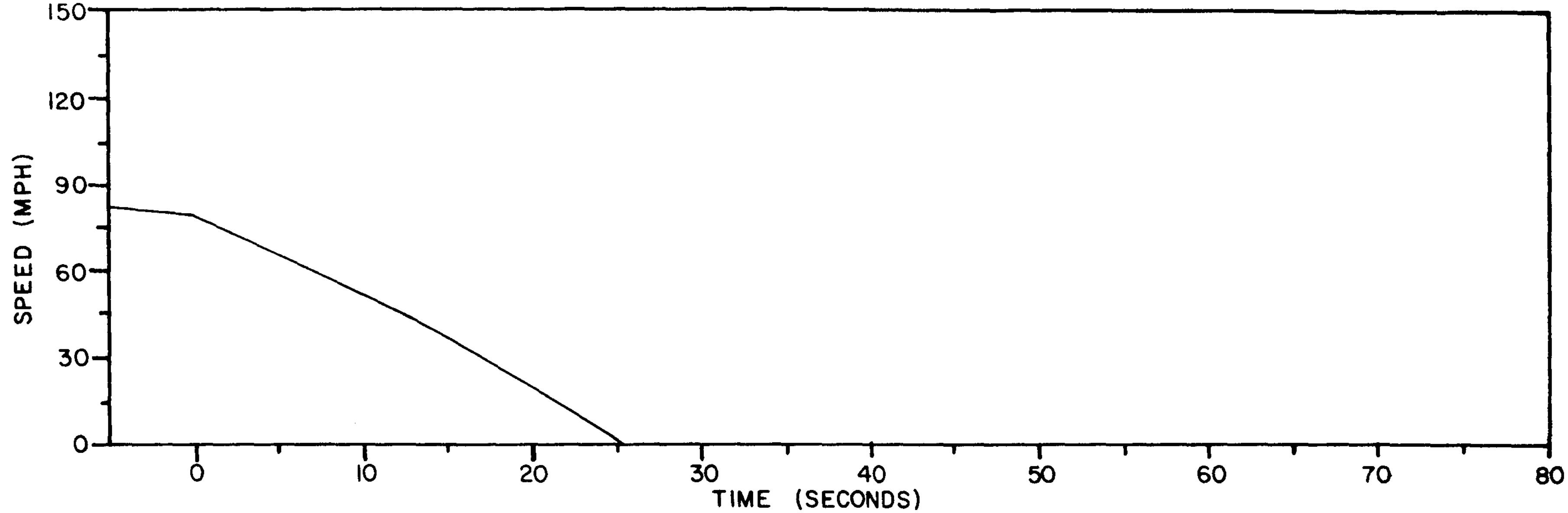

Figure B-51. Car No. 21044 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 121201

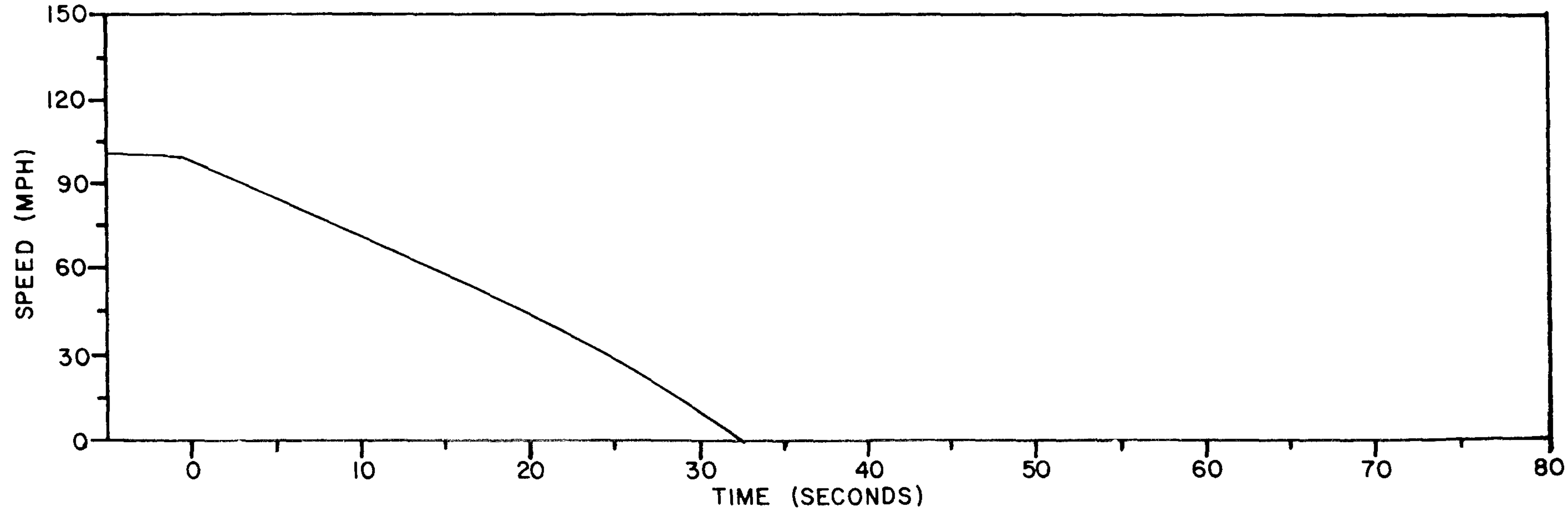

Figure B-52. Car No. 21044 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 121208

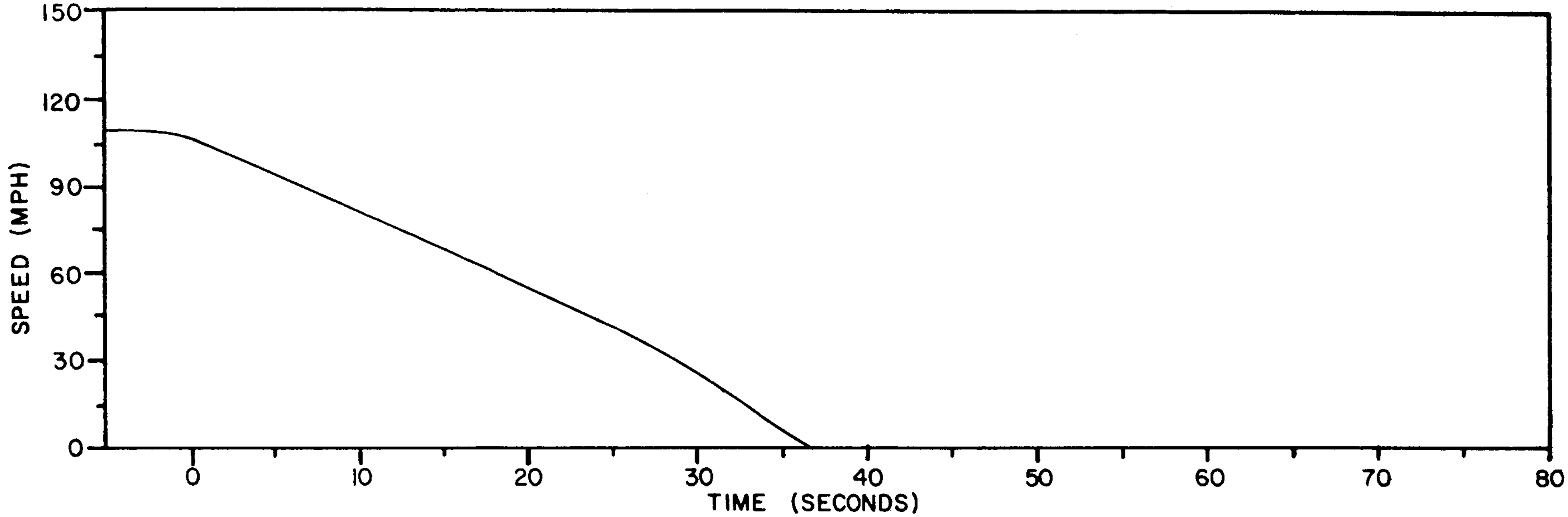

Figure B-53. Car No. 21044 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 121212

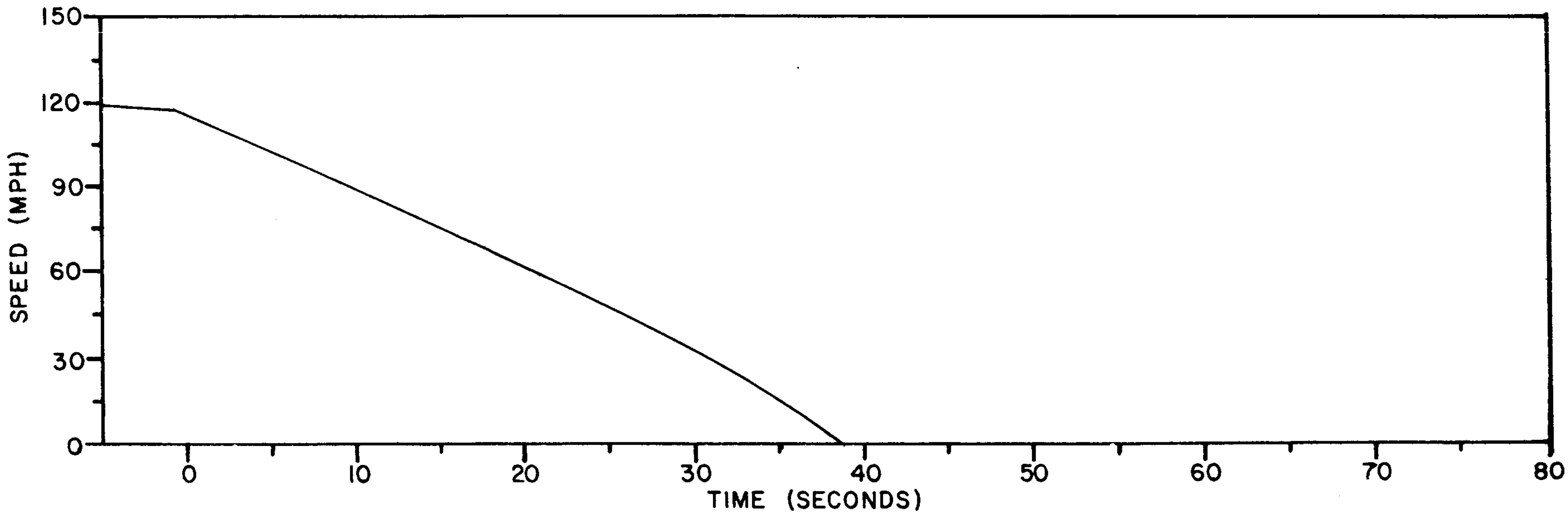

Figure B-54. Car No. 21044 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 121210

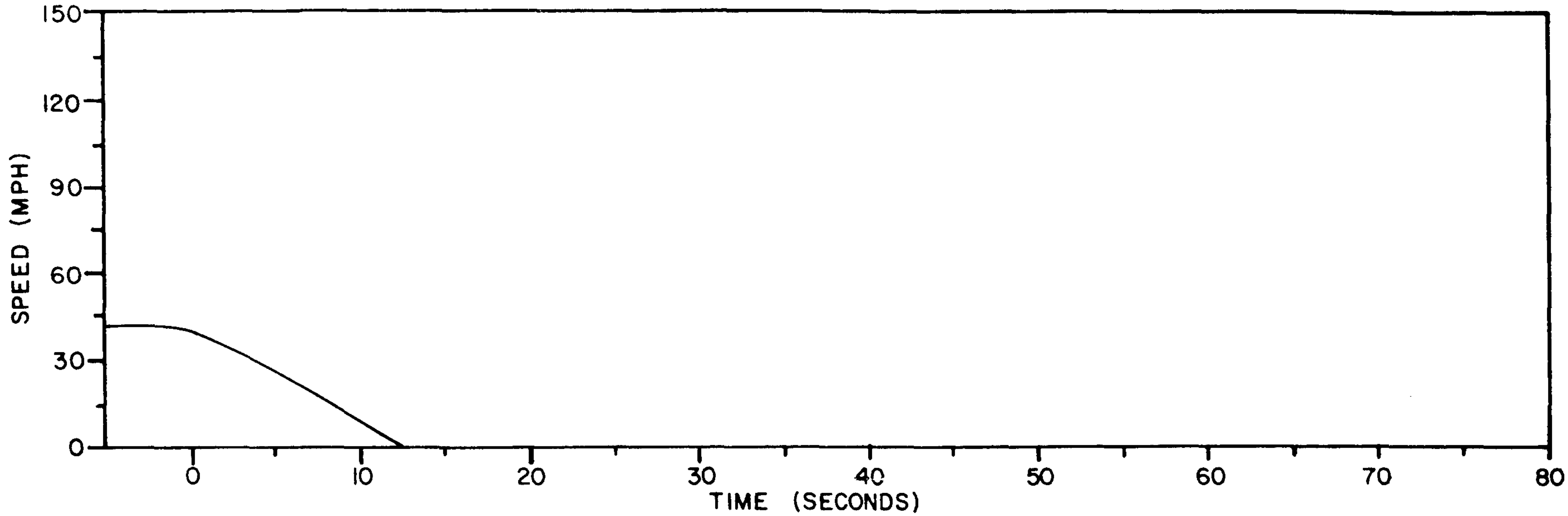

Figure B-55. Car No. 21044 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 121411

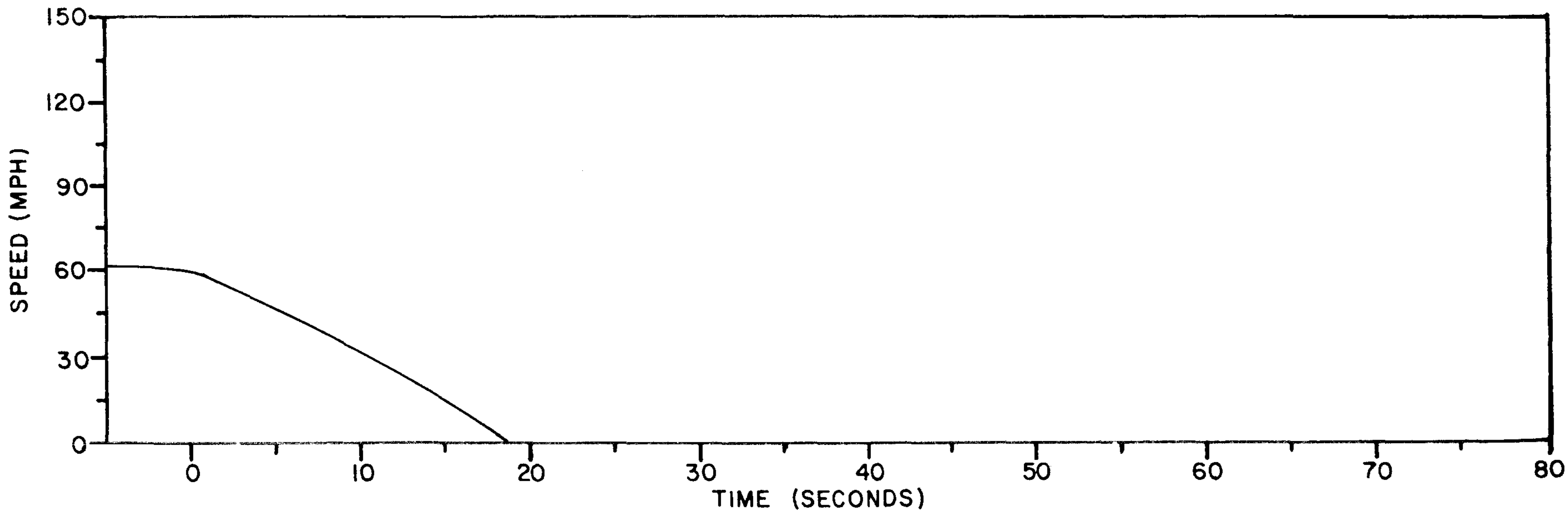

Figure B-56. Car No. 21044 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 121409

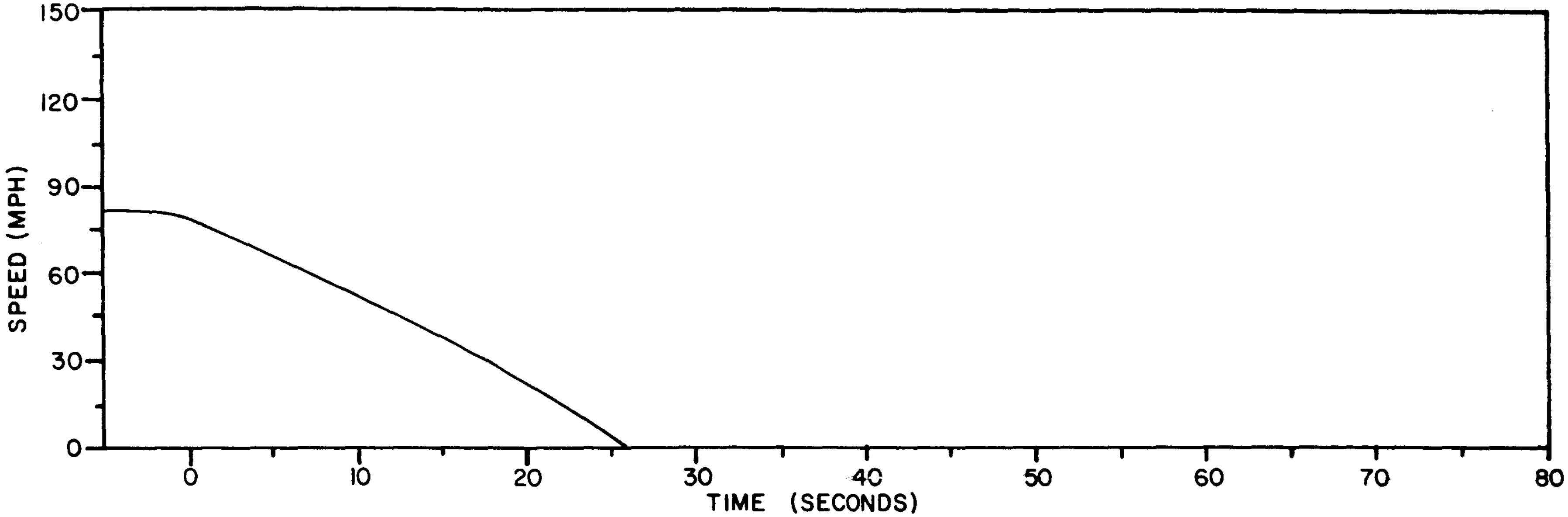

Figure B-57. Car No. 21044 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 121407

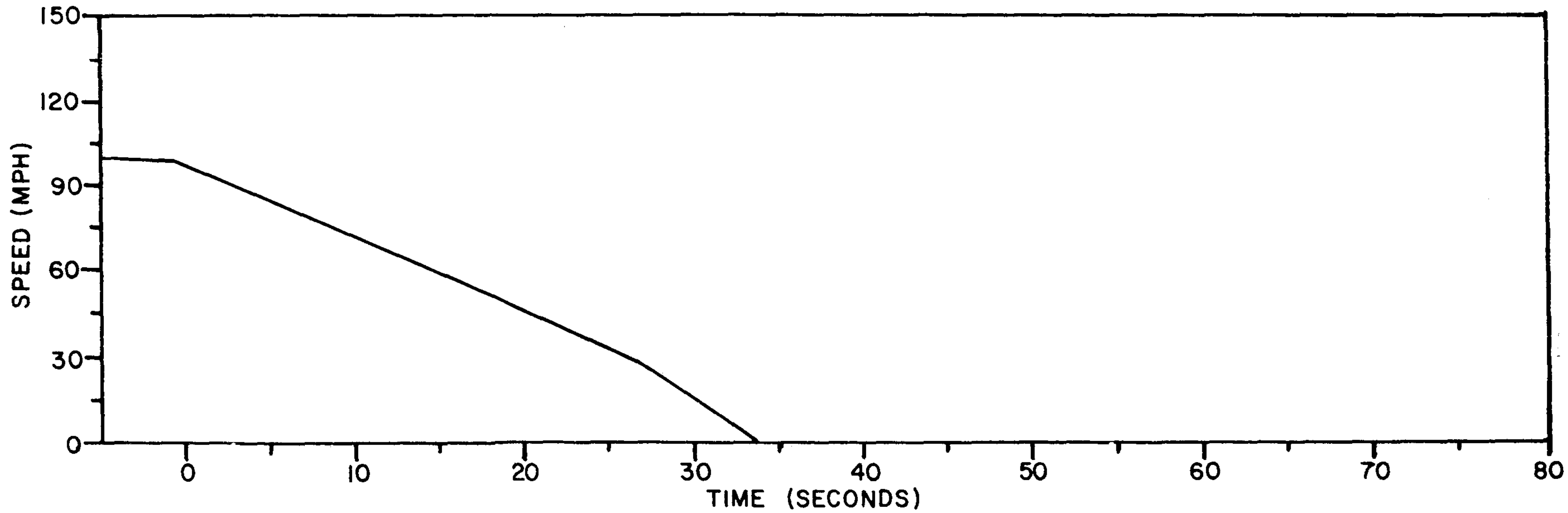

Figure B-58. Car No. 21044 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 121408

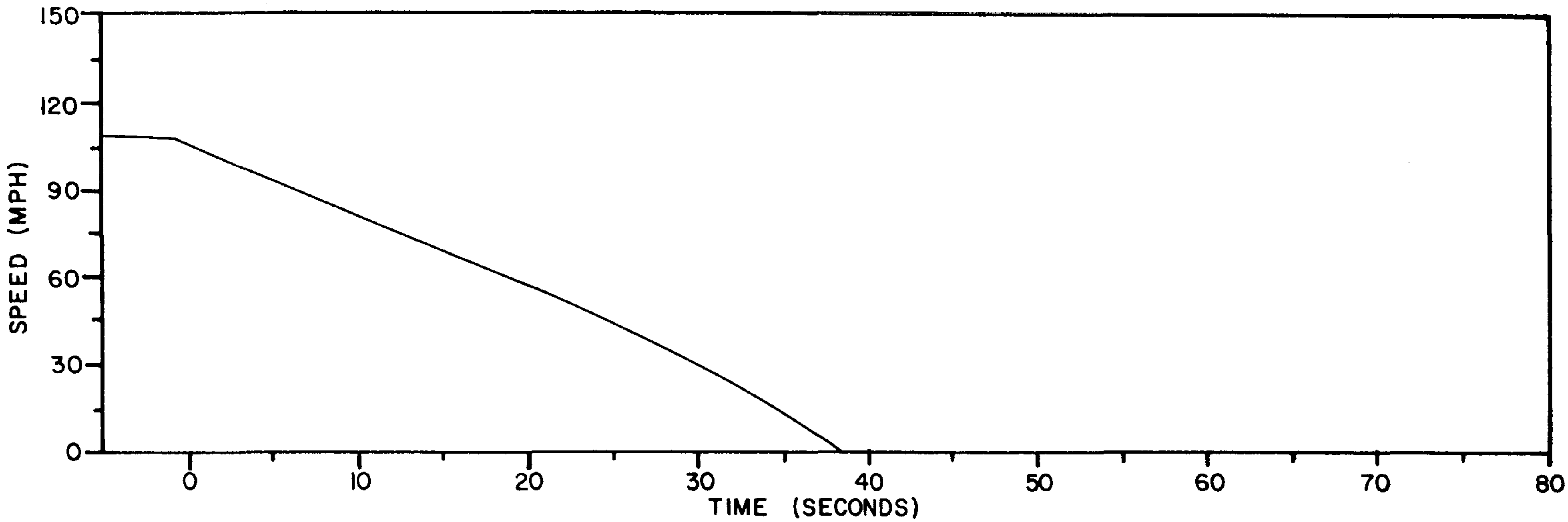

Figure B-59. Car No. 21044 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 121410

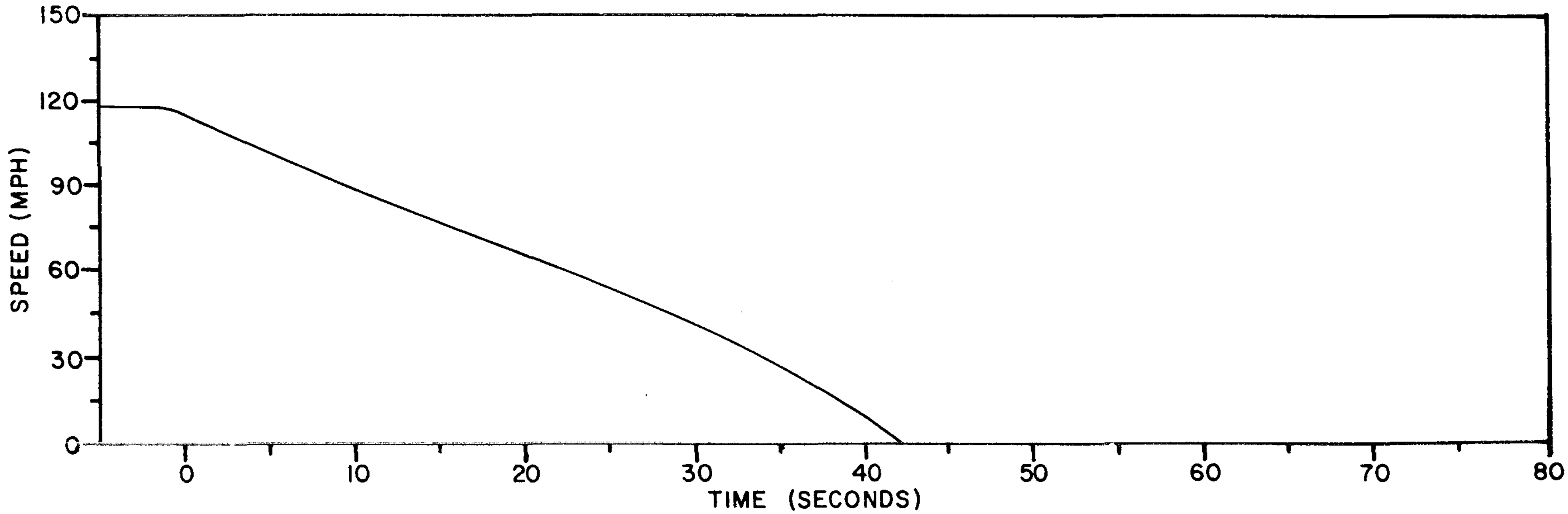

Figure B-60. Car No. 21044 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 121412

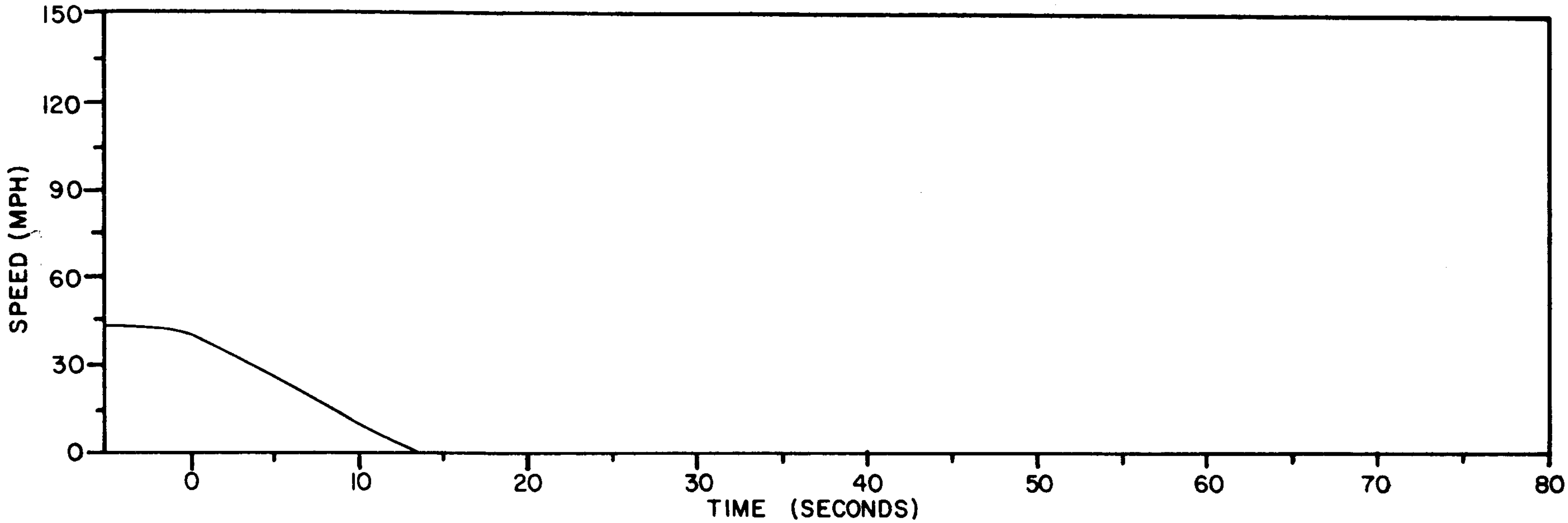

Figure B-61. Car No. 21063 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 010905

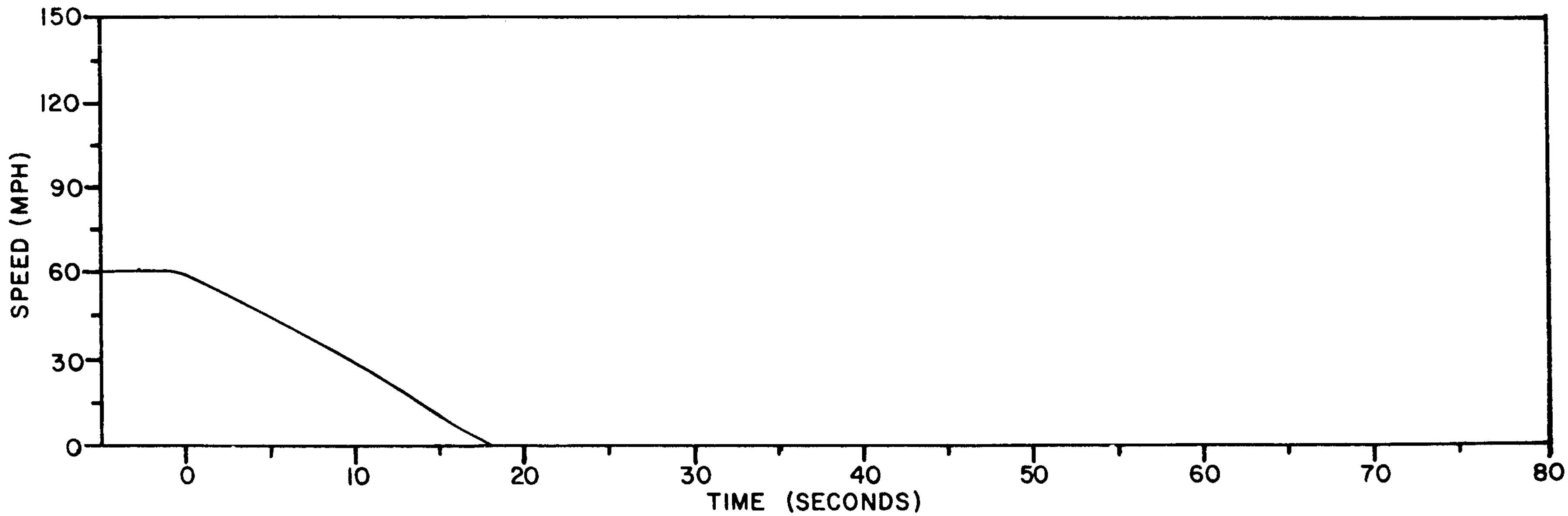

Figure B-62. Car No. 21063 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 010907

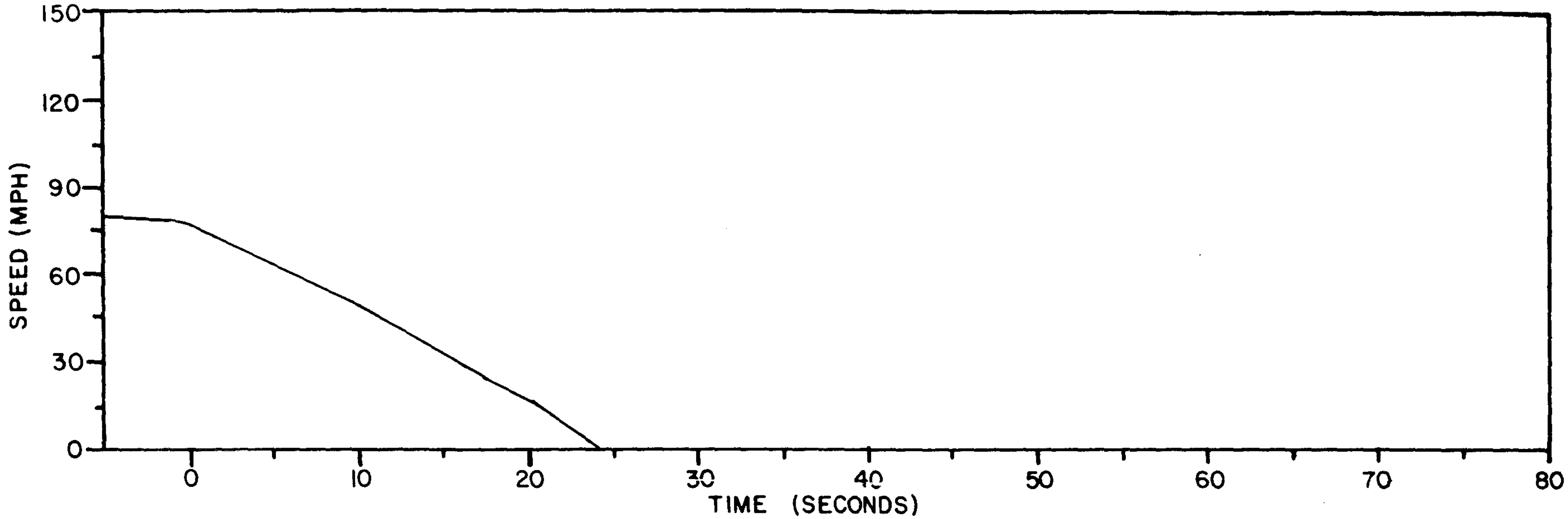

Figure B-63. Car No. 21063 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 010903

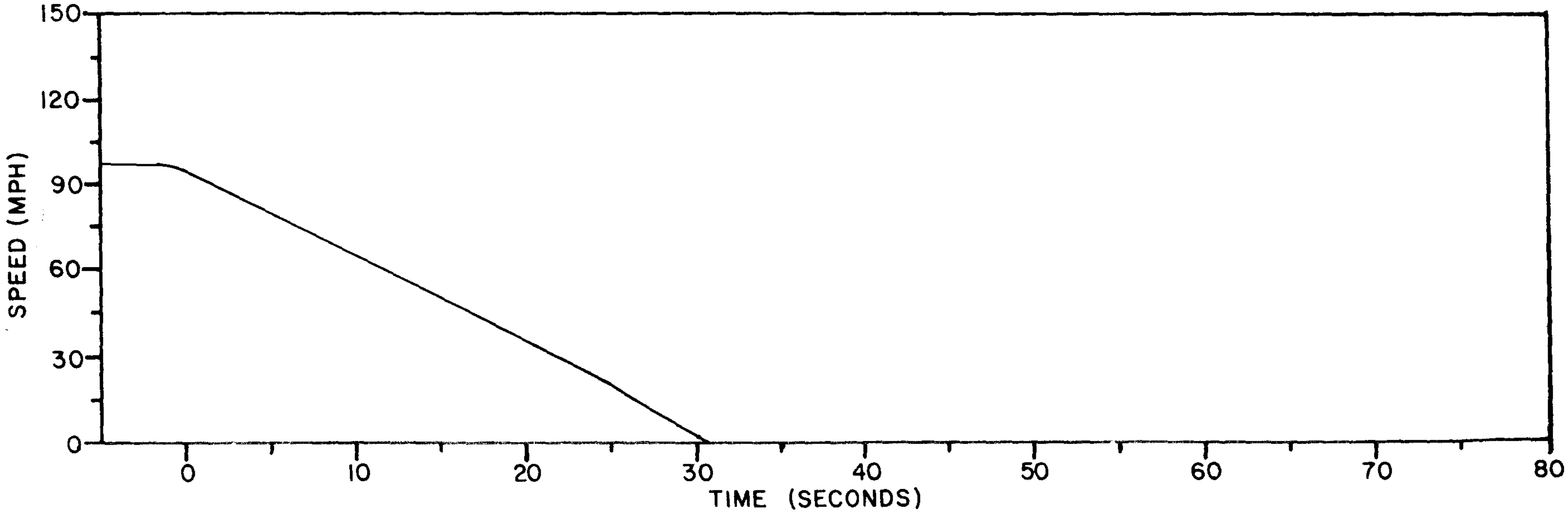

Figure B-64. Car No. 21063 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 010904

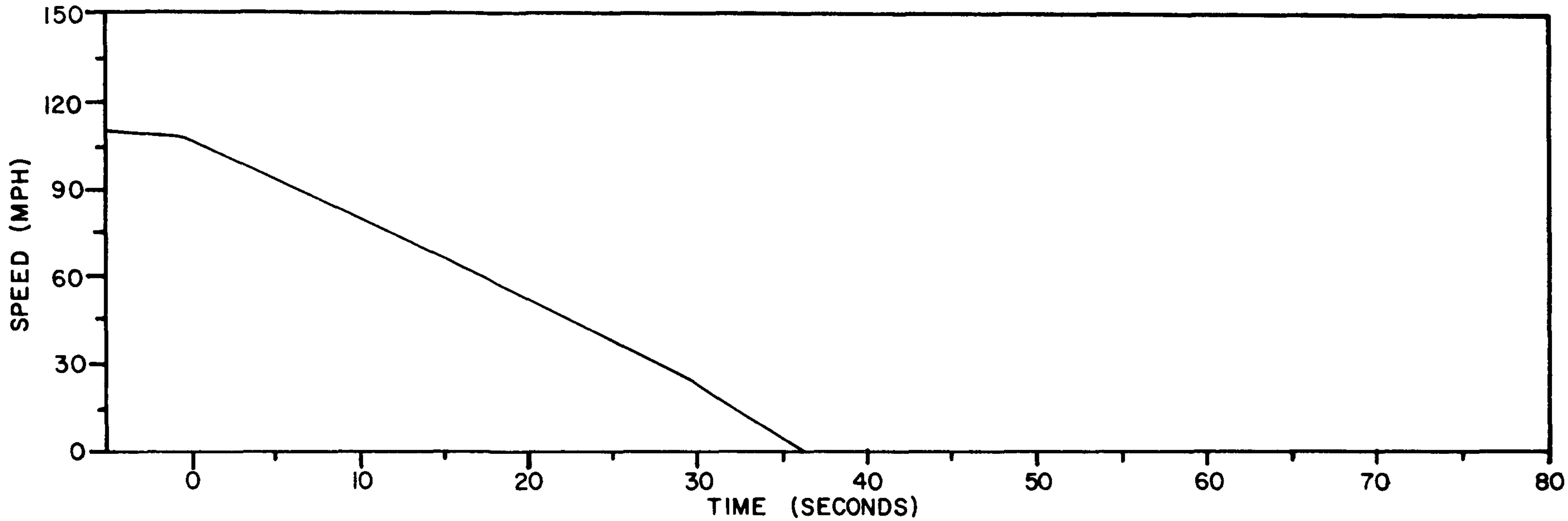

Figure B-65. Car No. 21063 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 010908

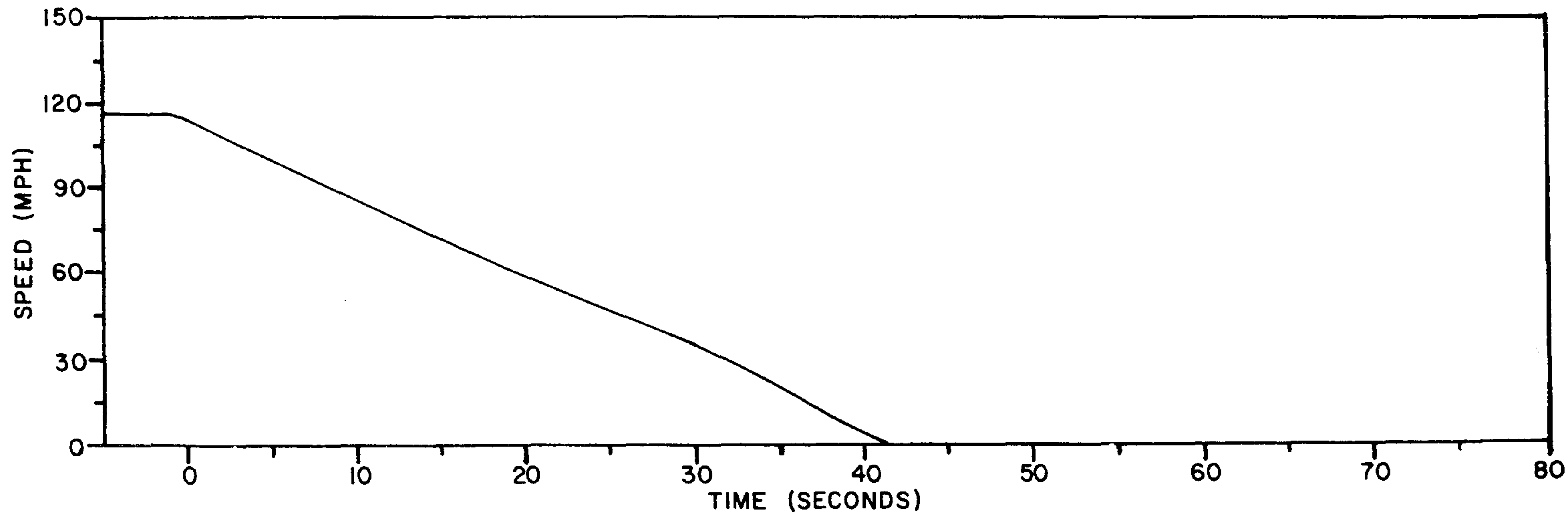

Figure B-66. Car No. 21063 - Emergency Service (50/50 Disc/Tread Ratio) - Run No. 010906

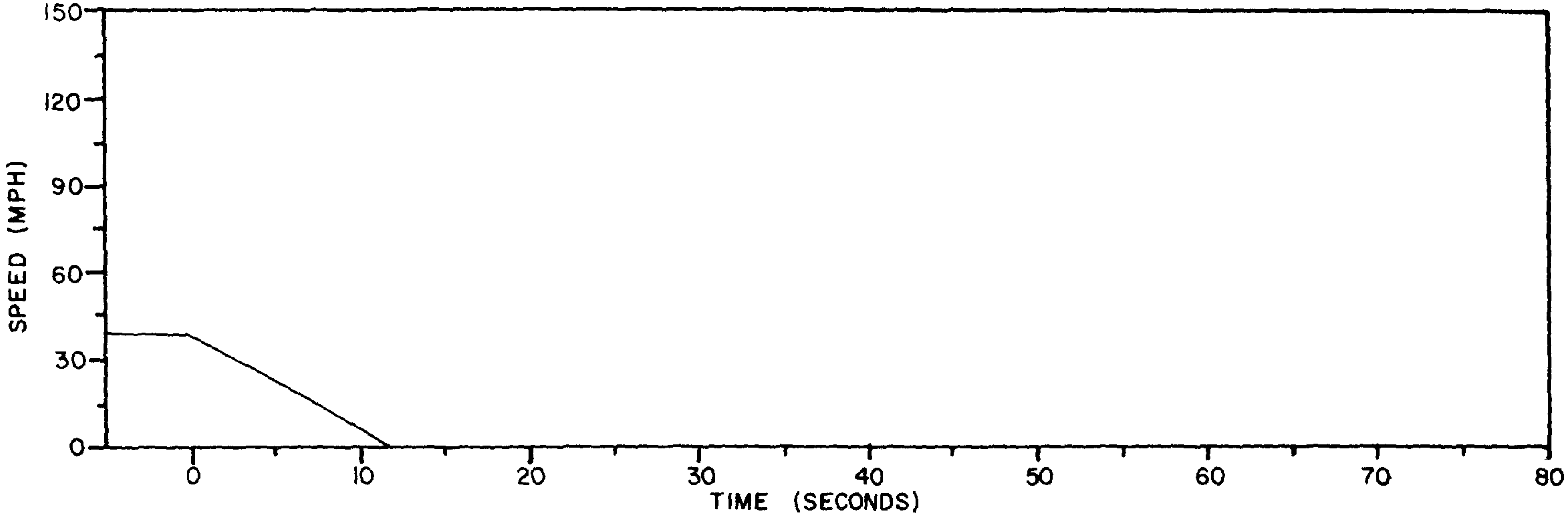

Figure B-67. Car No. 21063 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 011111

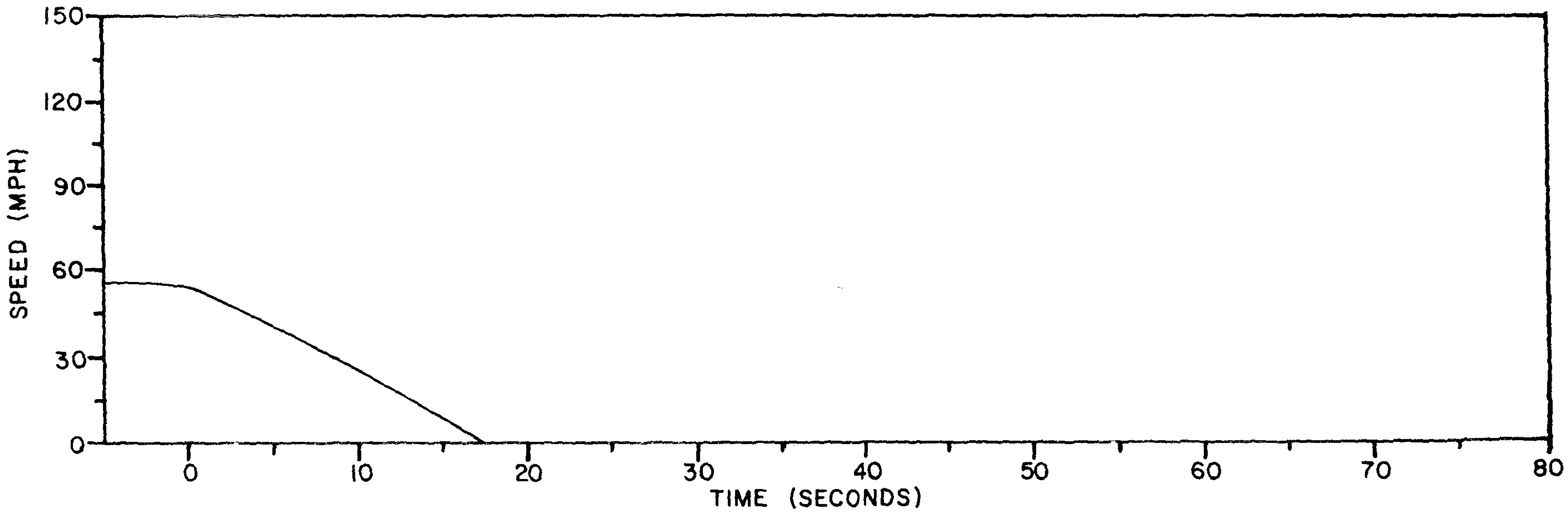

Figure B-68. Car No. 21063 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 011109

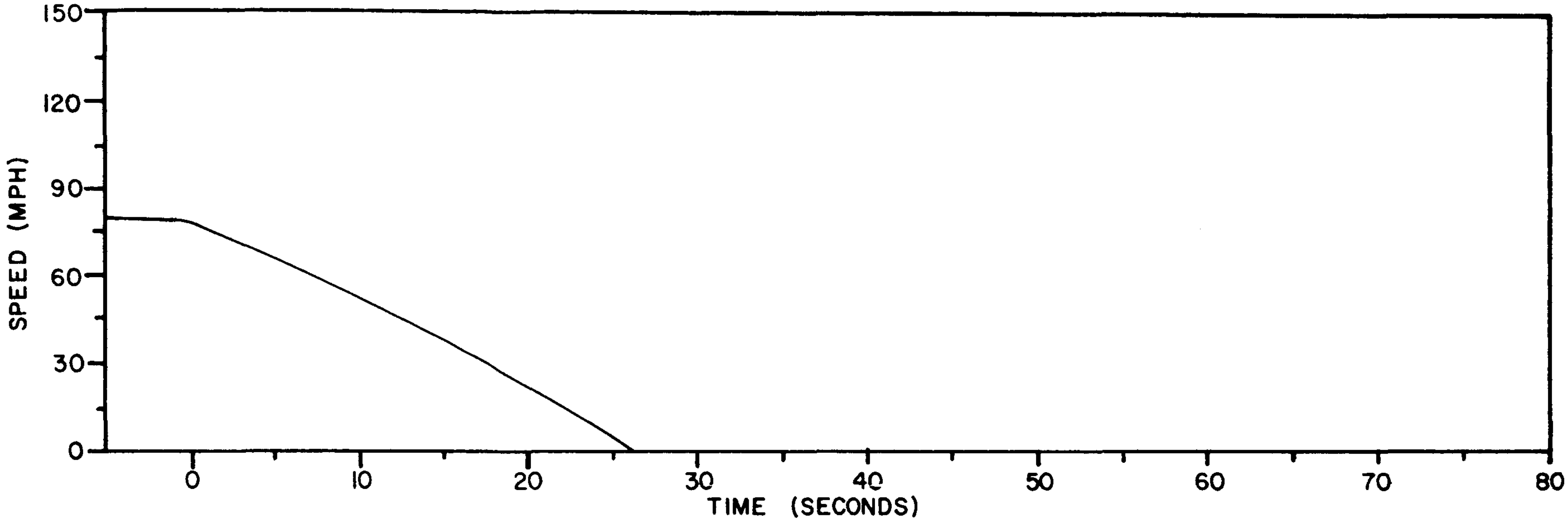

Figure B-69. Car No. 21063 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 011107

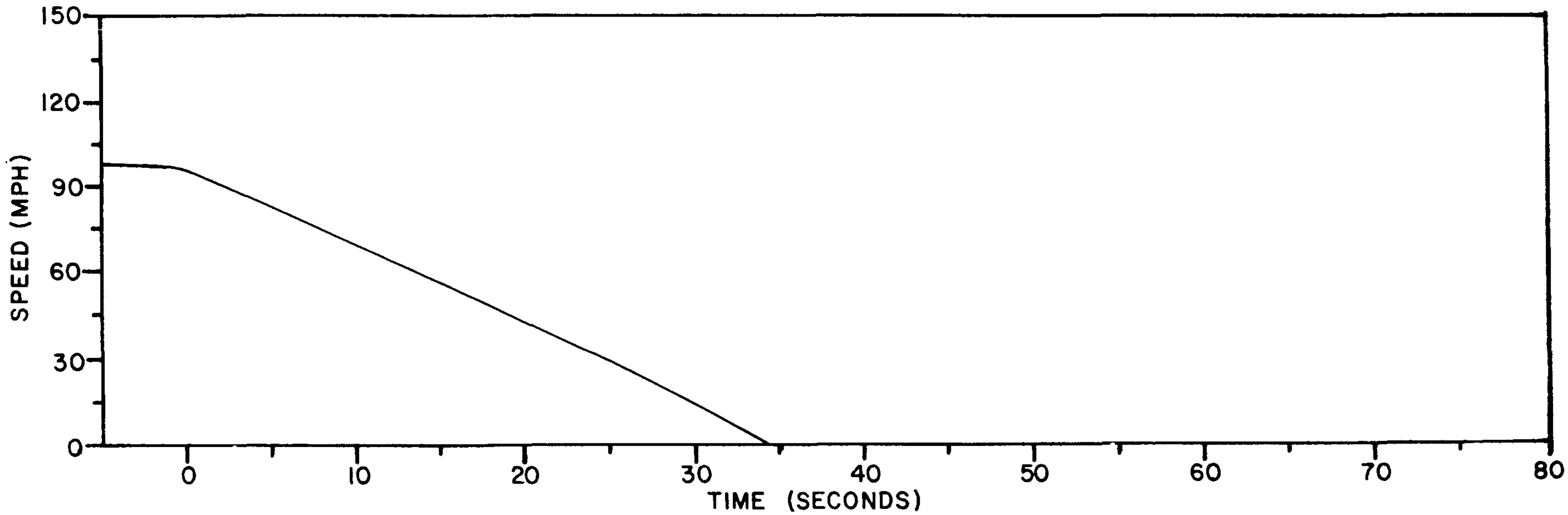

Figure B-70. Car No. 21063 - Emergency Service (60/40 Disc/Treat Ratio) - Run No. 011108

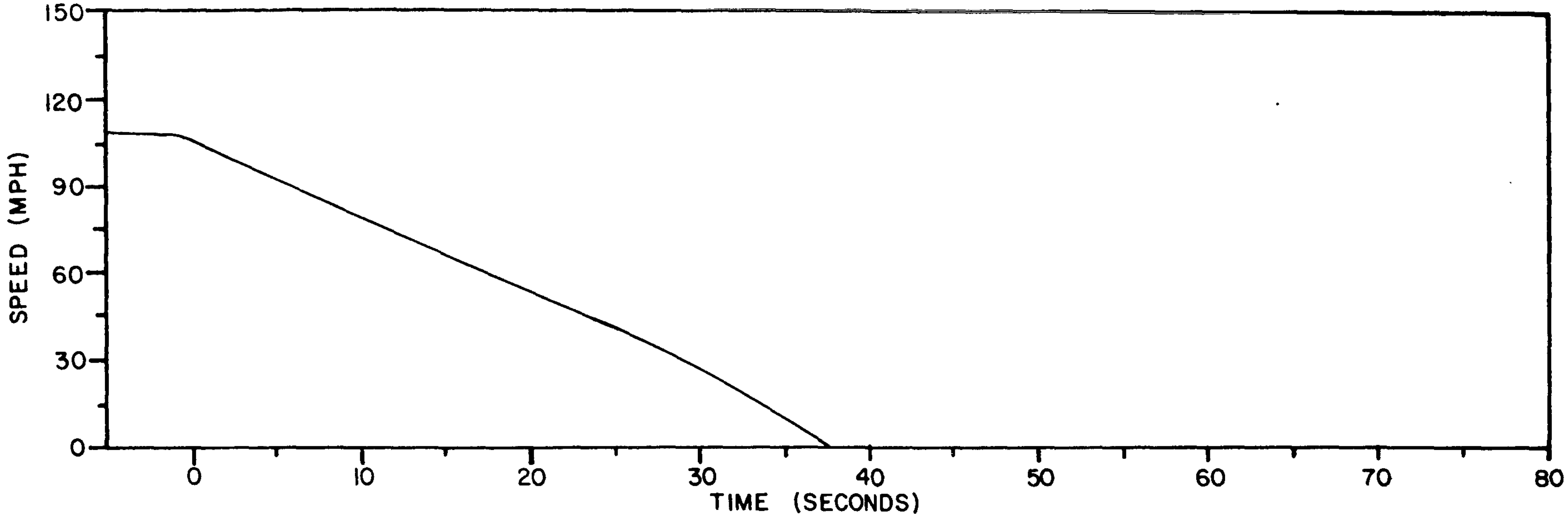

Figure B-71. Car No. 21063 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 011110

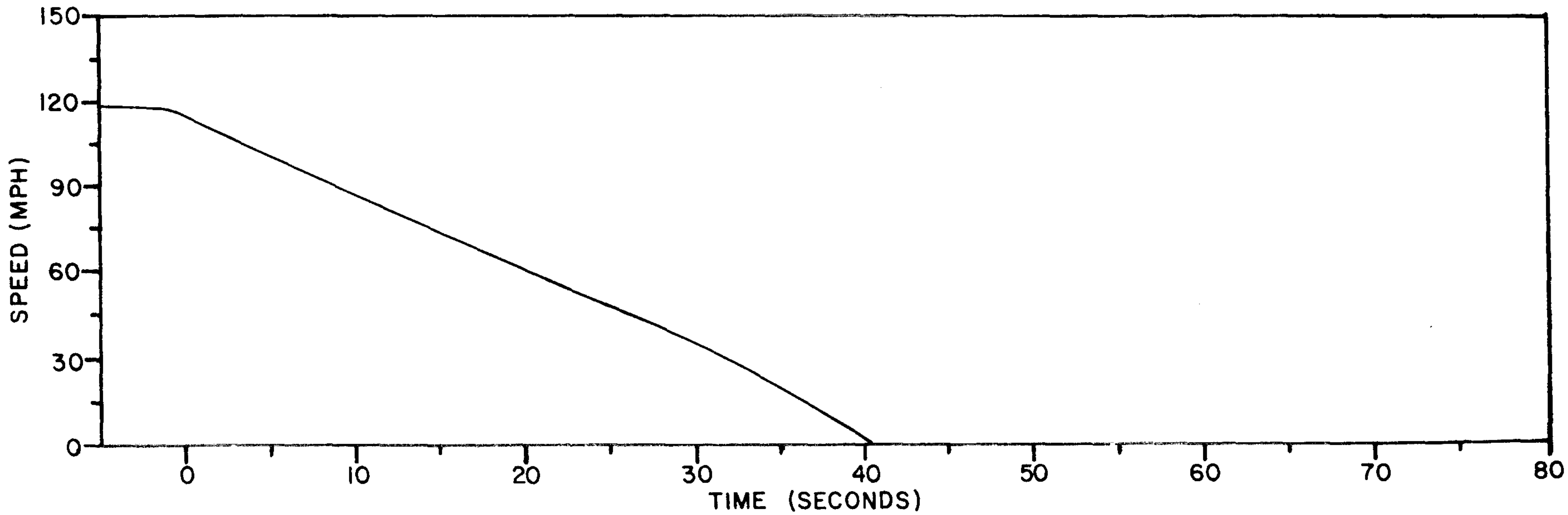

Figure B-72. Car No. 21063 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 011112

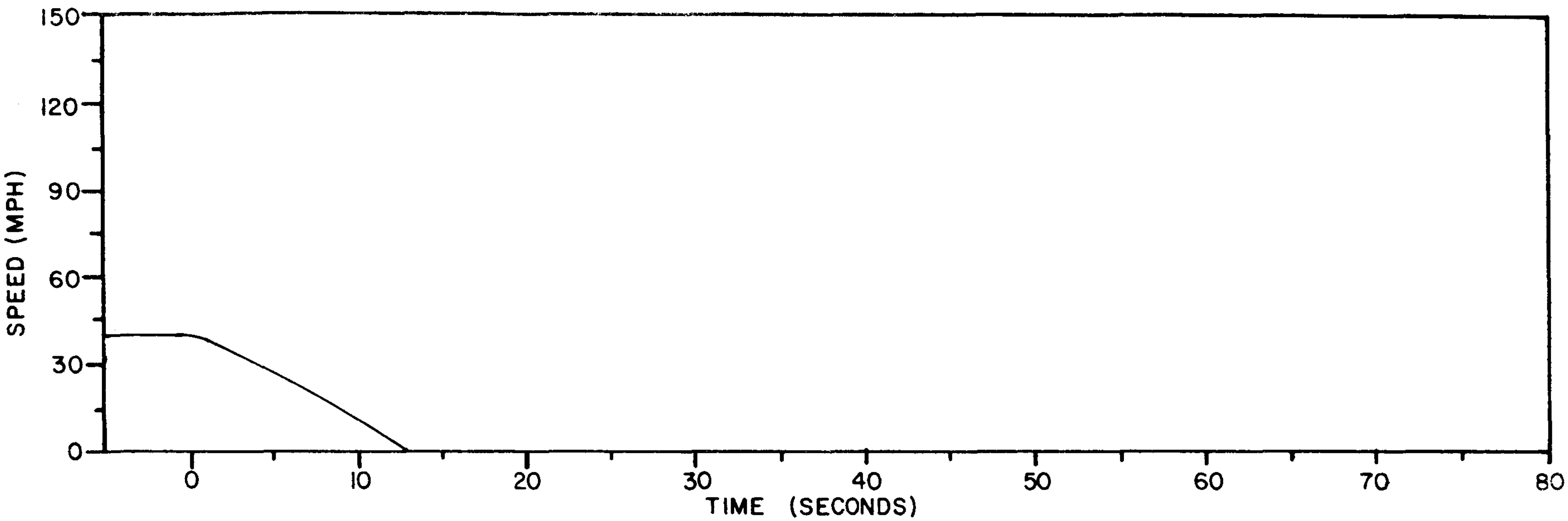

Figure B-73. Car No. 21087 - Emergency Service (70/30 Disc/Tread Ratio) - Run No. 013101

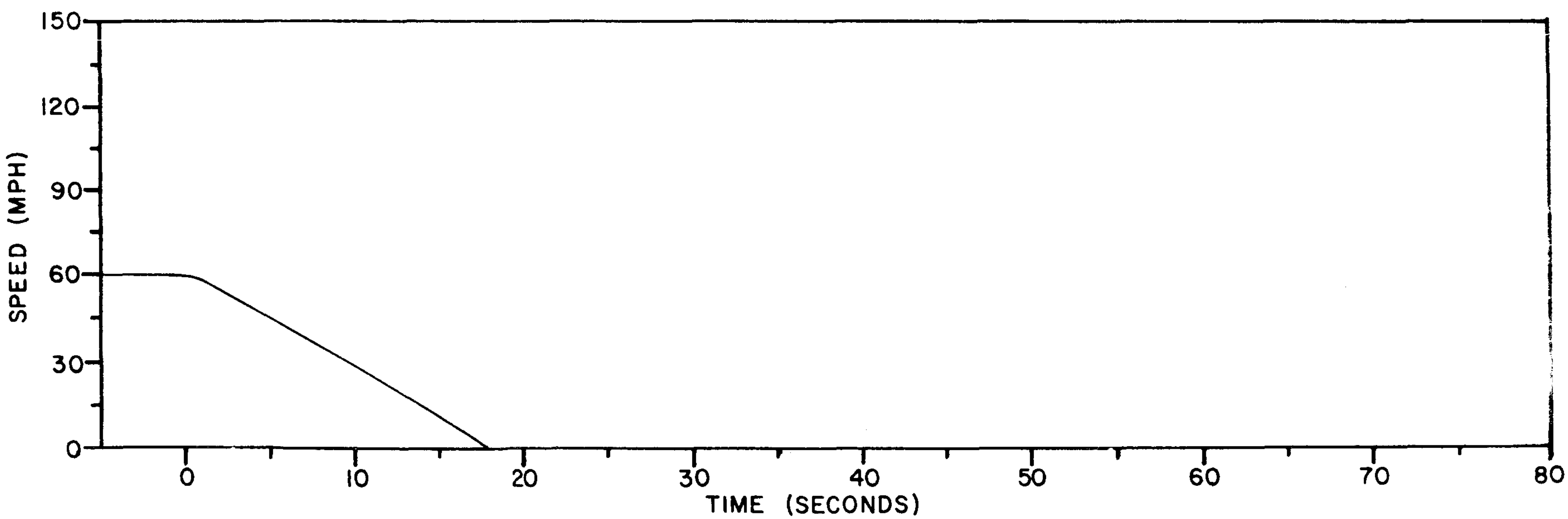

Figure B-74. Car No. 21087 - Emergency Service (70/30 Disc/Tread Ratio) - Run No. 013103

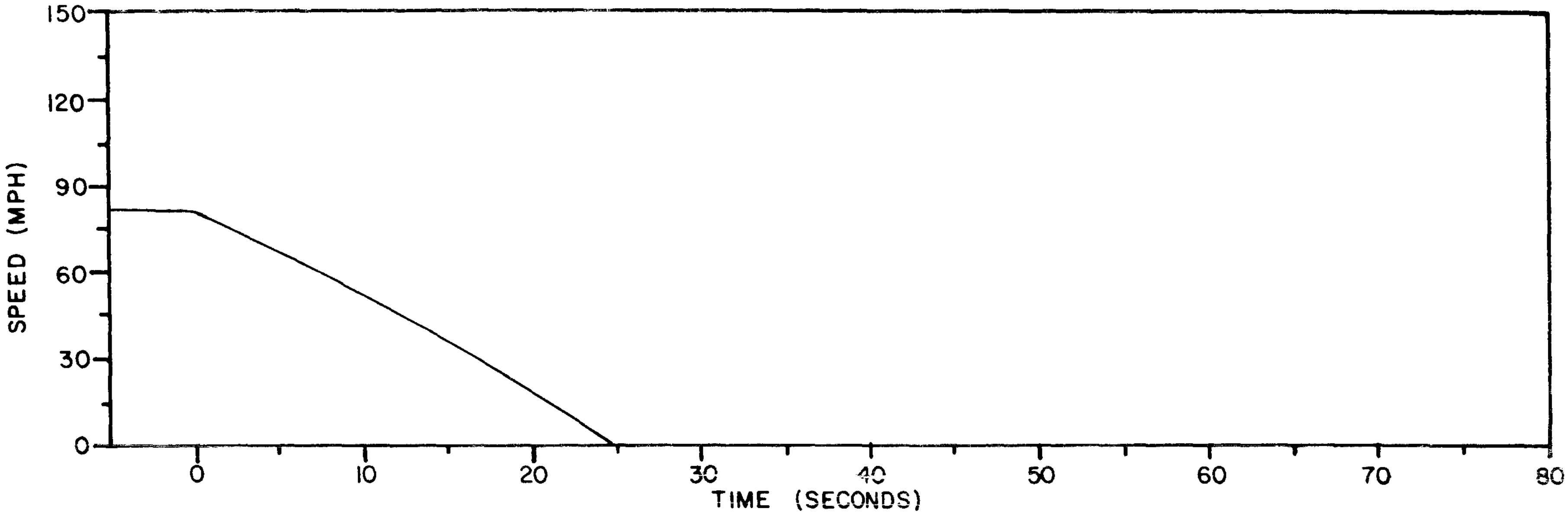

Figure B-75. Car No. 21087 - Emergency Service (70/30 Disc/Tread Ratio) - Run No. 013003

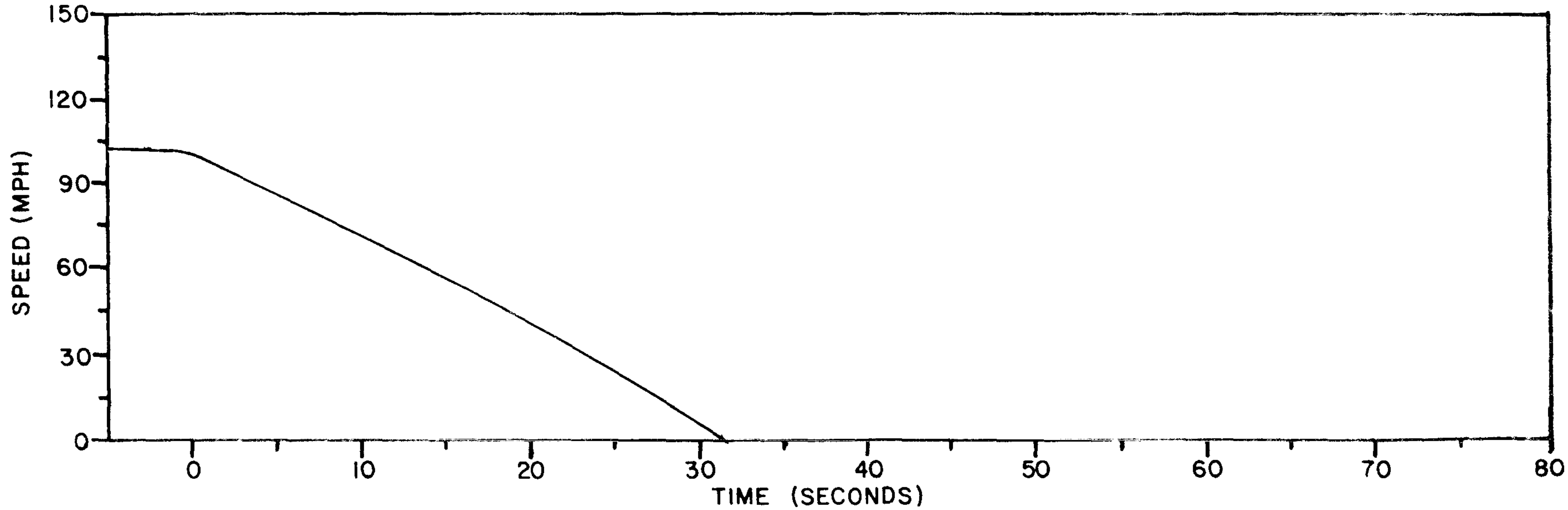

Figure B-76 Car No. 21087 - Emergency Service (70/30 Disc/Tread Ratio) - Run No. 013004

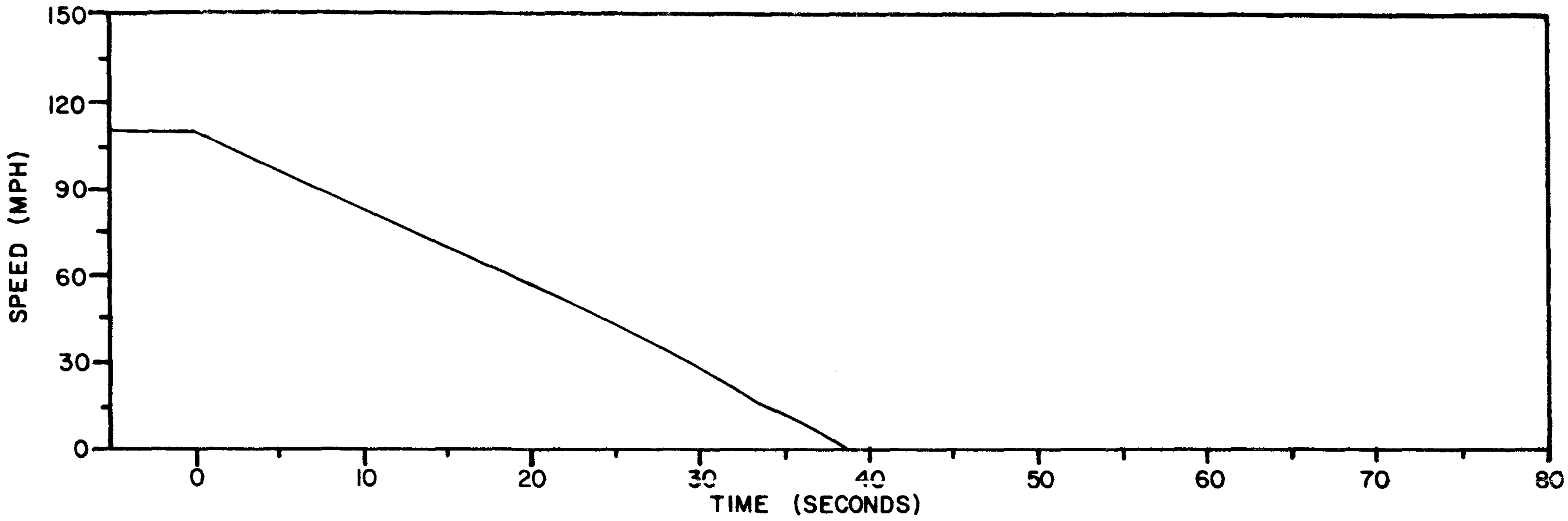

Figure B-77. Car No. 21087 - Emergency Service (70/30 Disc/Tread Ratio) - Run No. 013005

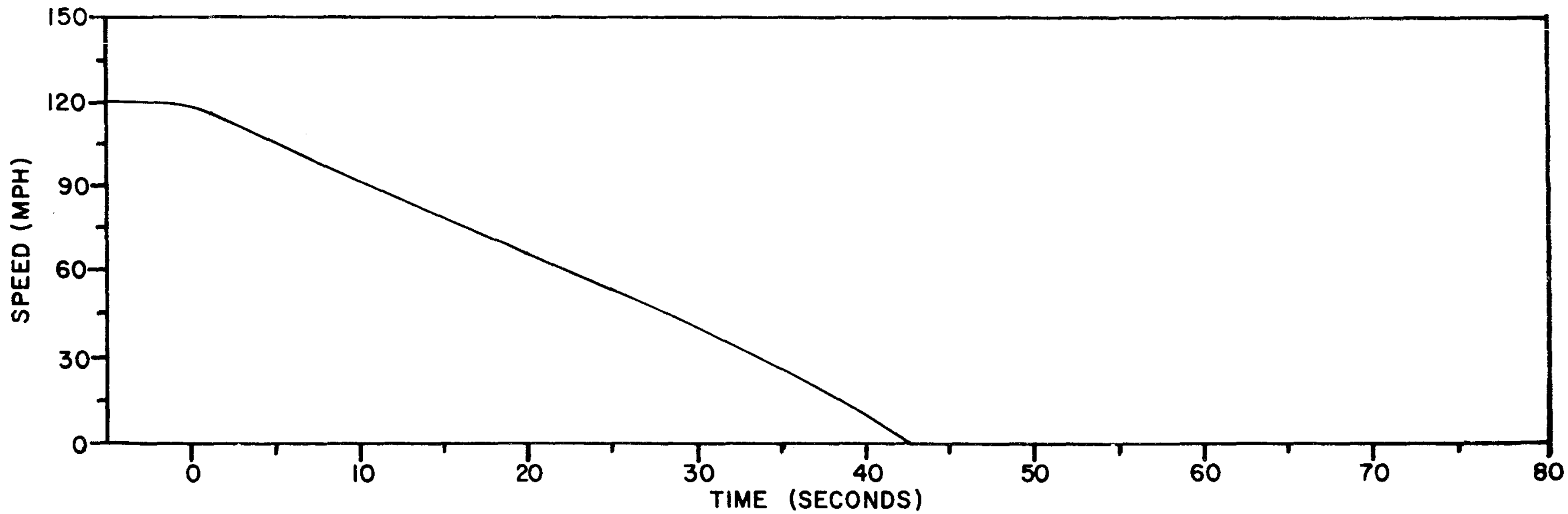

Figure B-78. Car No. 21087 - Emergency Service (70/30 Disc/Tread Ratio) - Run No. 013102

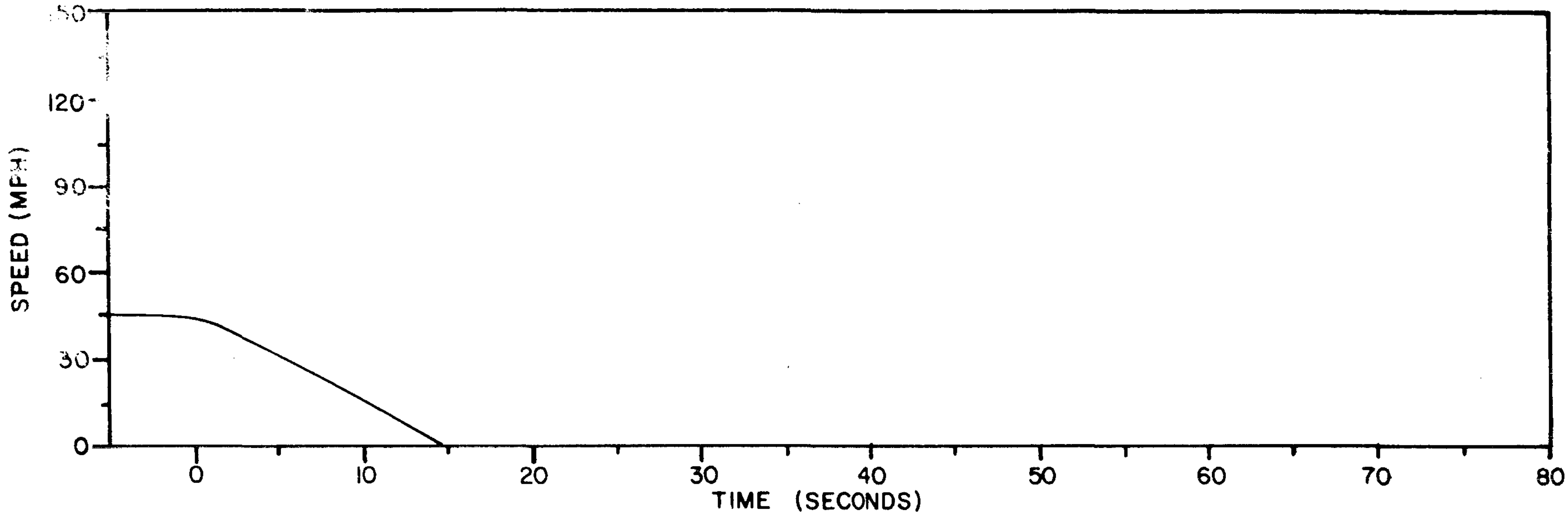

Figure B-79. Car No. 21087 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 013114

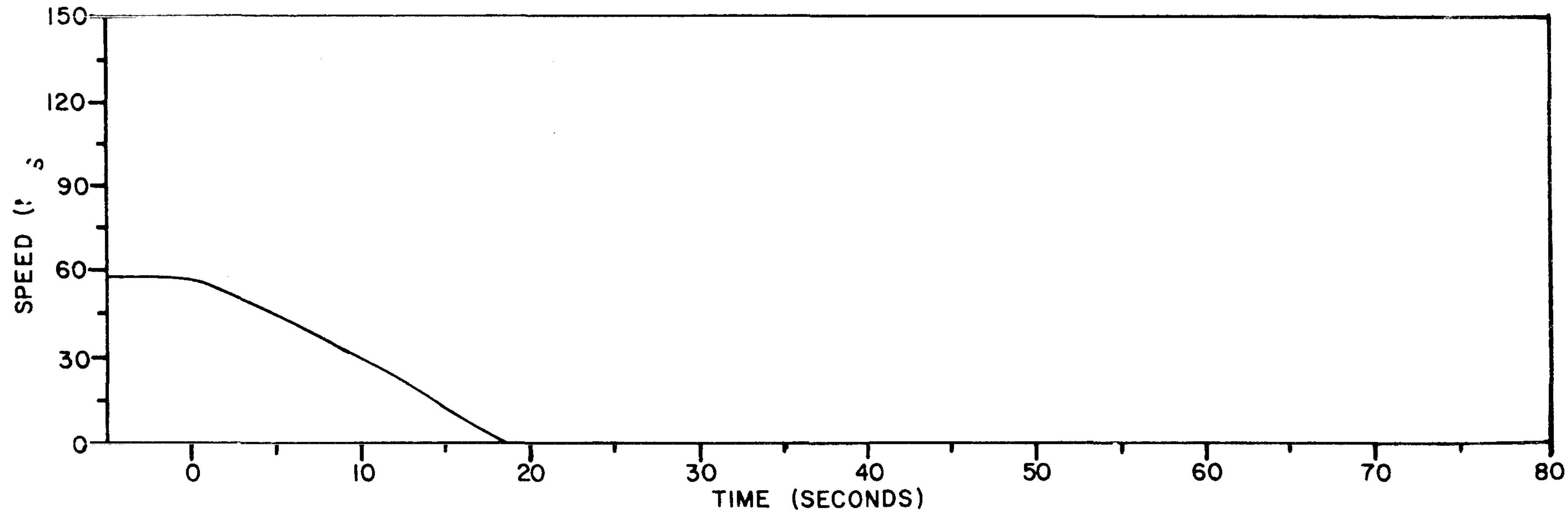

Figure B-80. Car No. 21087 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 013112

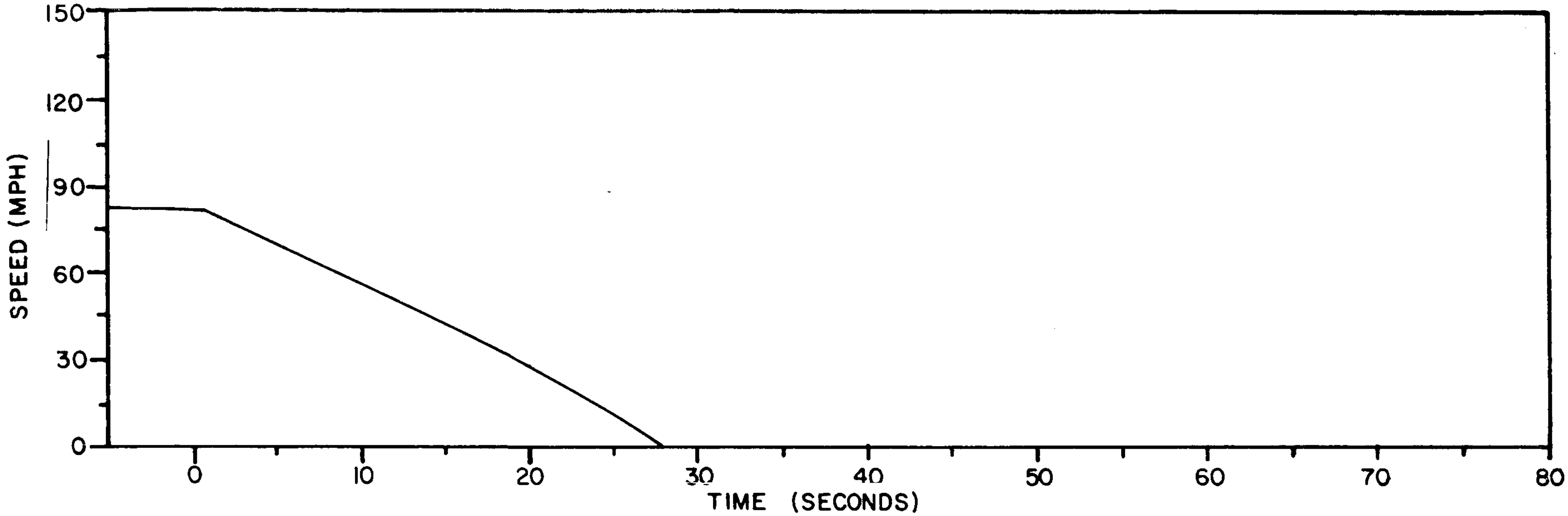

Figure B-81. Car No. 21087 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 013110

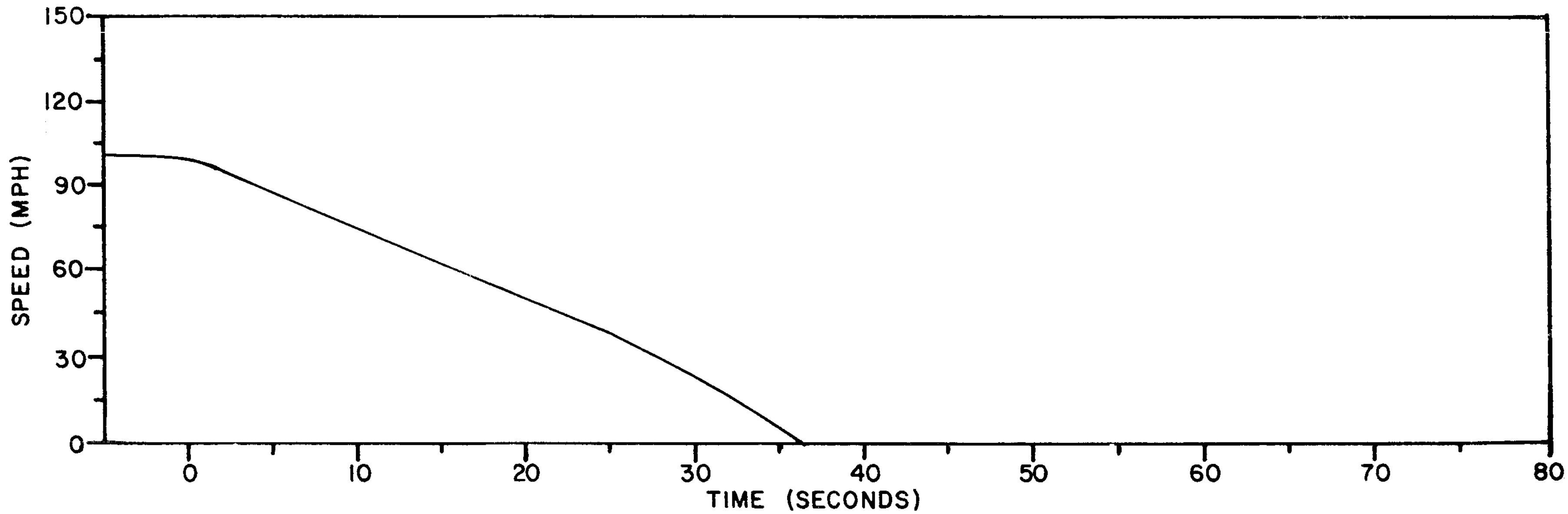

Figure B-82. Car No. 21087 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 013111

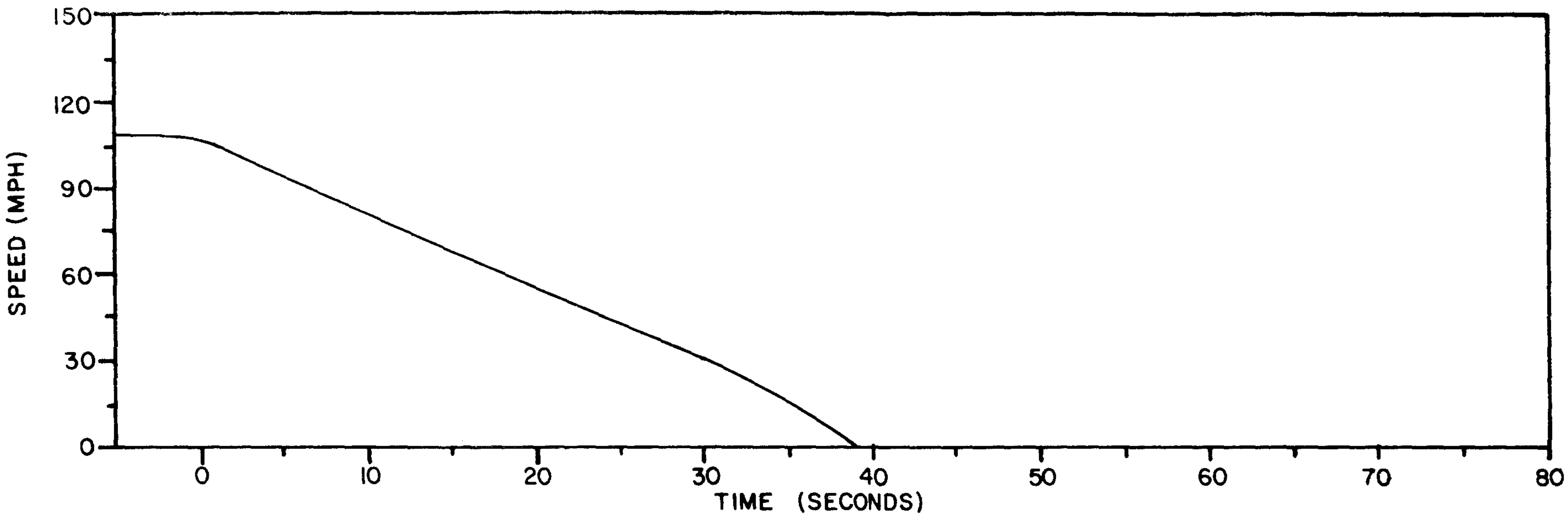

Figure B-83. Car No. 21087 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 013115

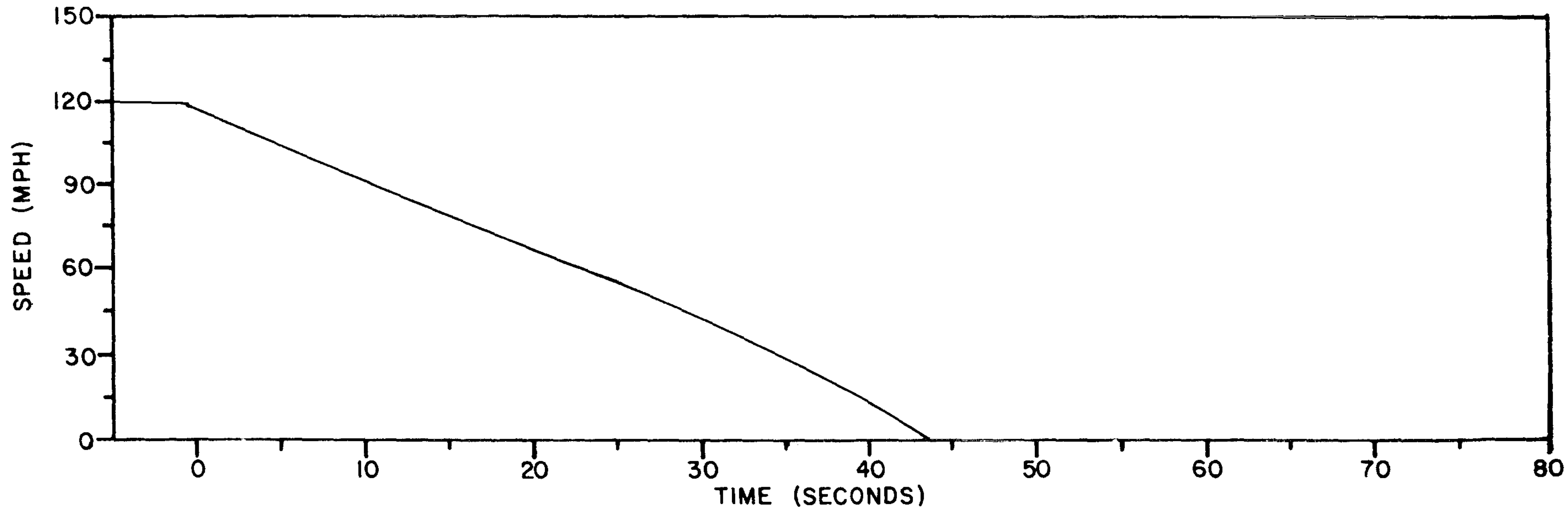

Figure B-84. Car No. 21087 - Emergency Service (60/40 Disc/Tread Ratio) - Run No. 013113

APPENDIX C

PEAK TEMPERATURES AND STOP TEMPERATURES

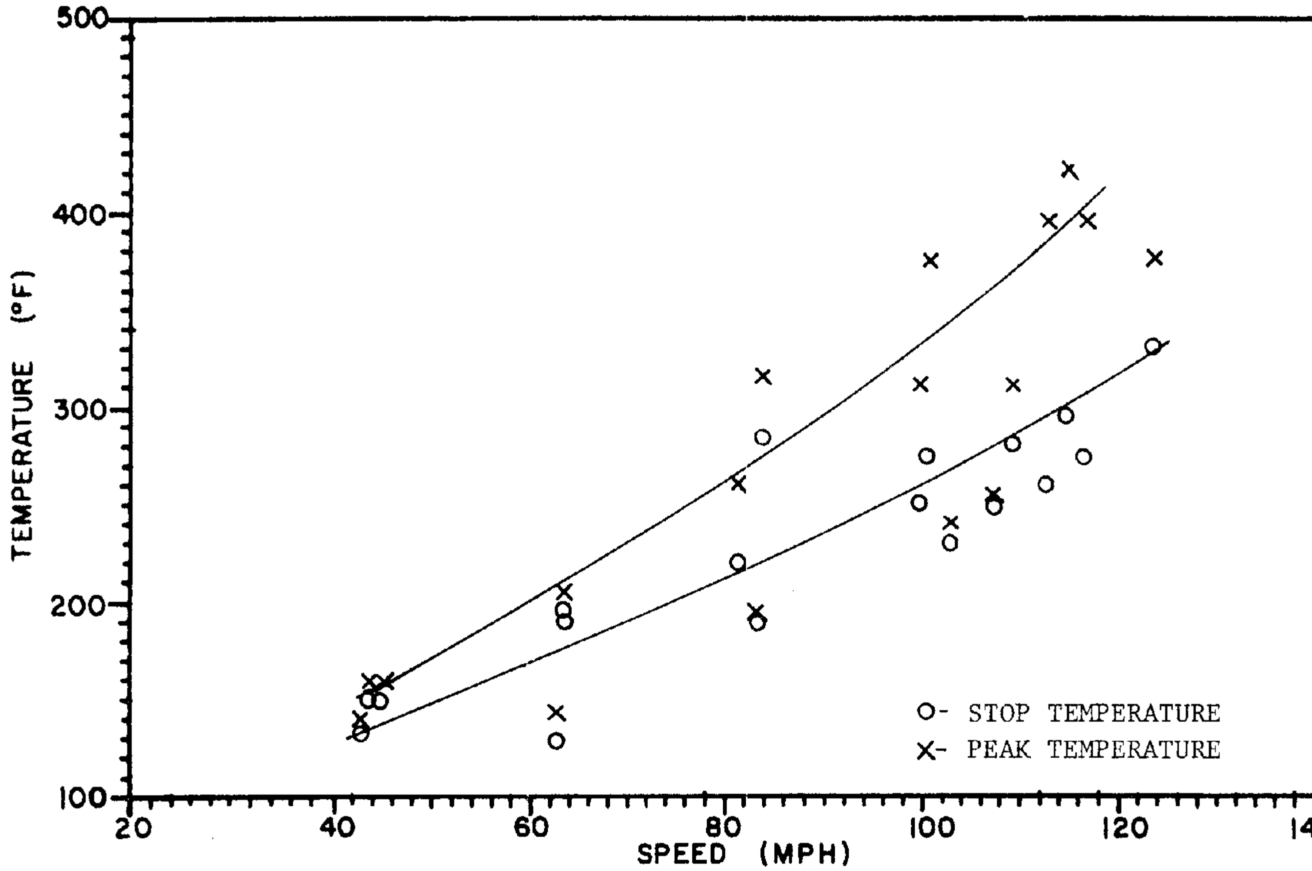

Figure C-1. Standard Car No. 21018 - Full Service Braking (68 PSI) Brake Cylinder Pressure

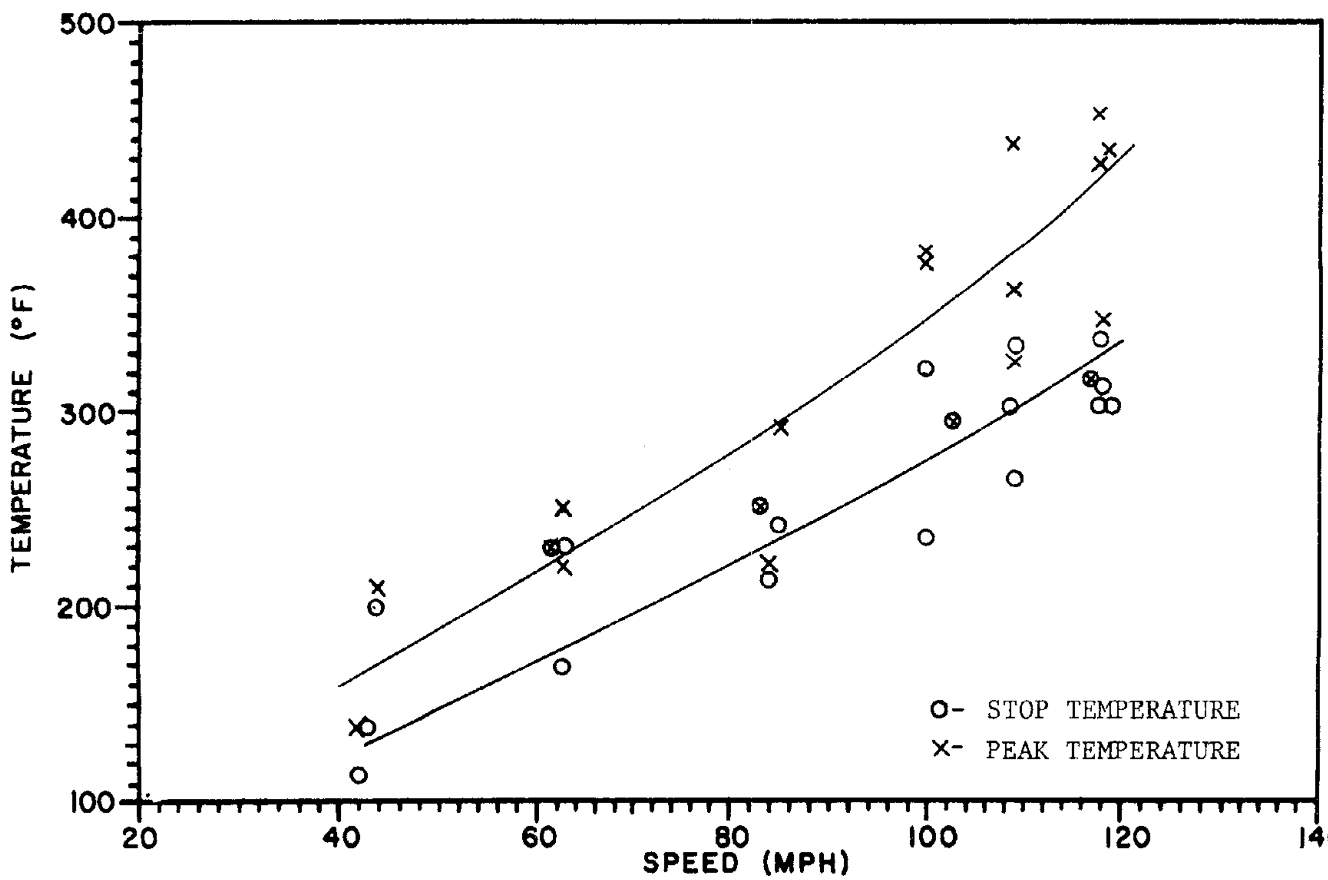

Figure C-2. Standard Car No. 21018 - Emergency Service Braking

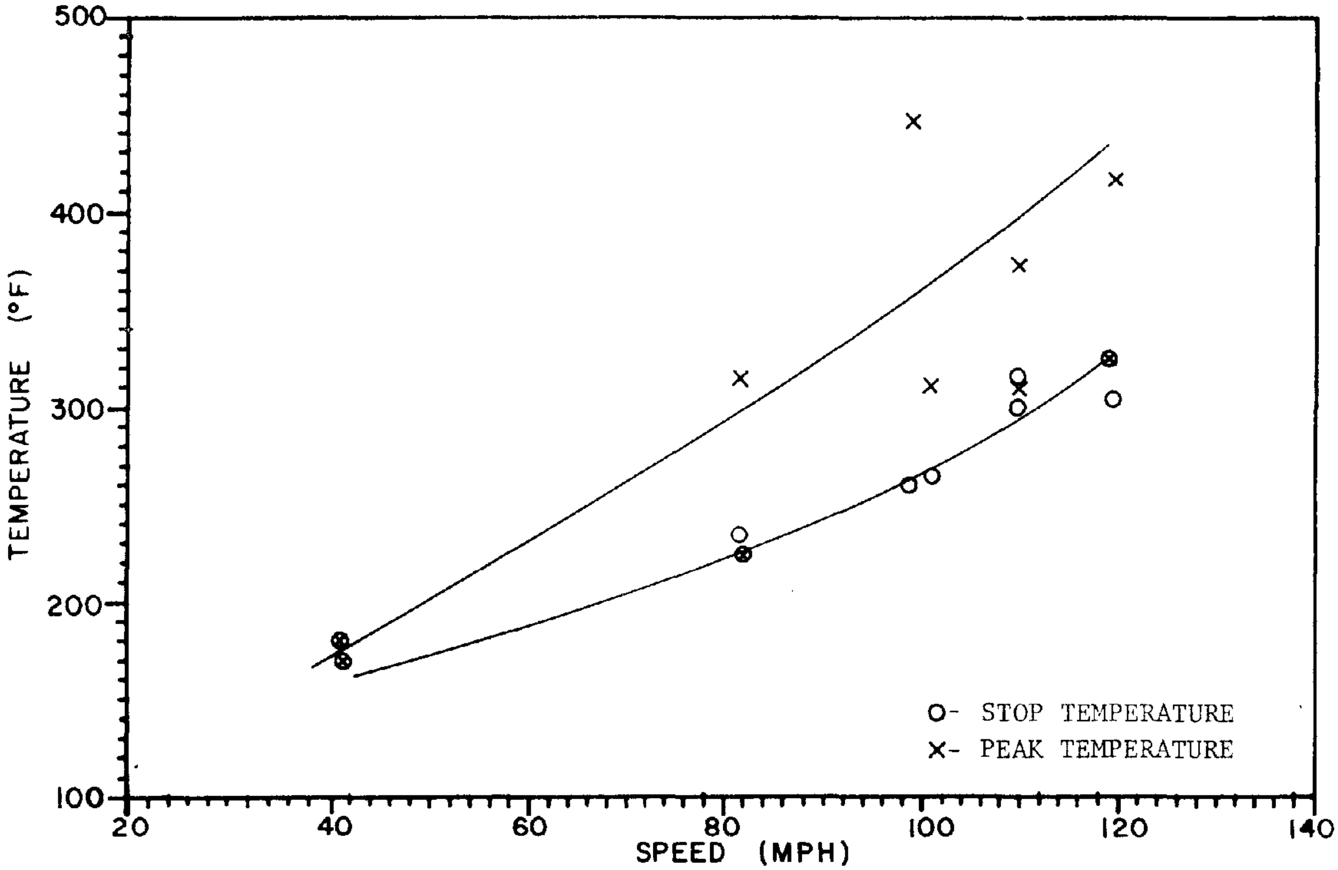

Figure C-3. Standard Car No. 21018 - Full Service Braking (55 PSI) Brake Cylinder Pressure

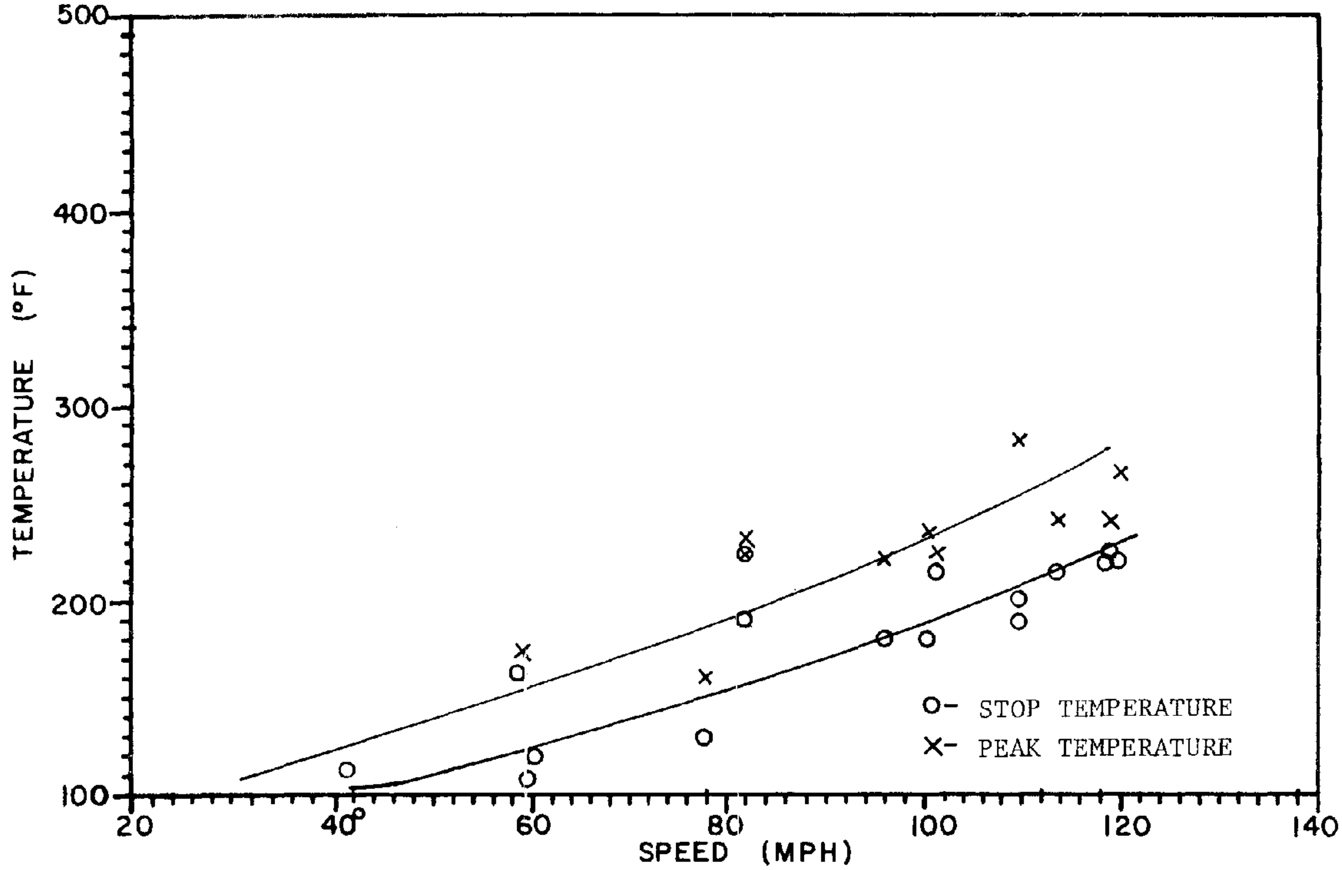

Figure C-4. Car No. 21044 - Full Service Braking, Disc Temperature, (50/50 Disc/Tread Ratio)

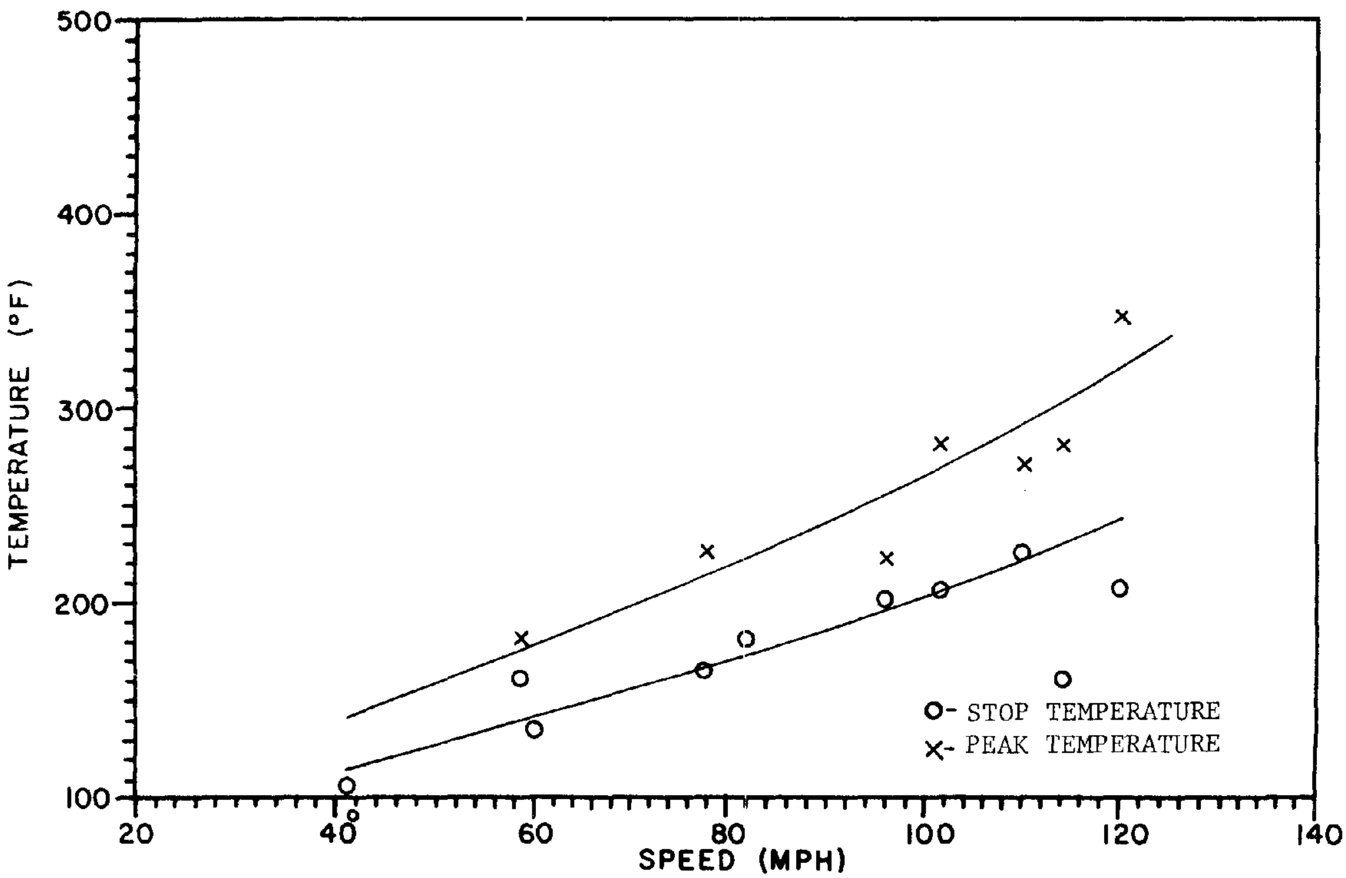

Figure C-5. Car No. 21044 - Full Service Braking, Tread Temperature, (50/50 Disc/Tread Ratio)

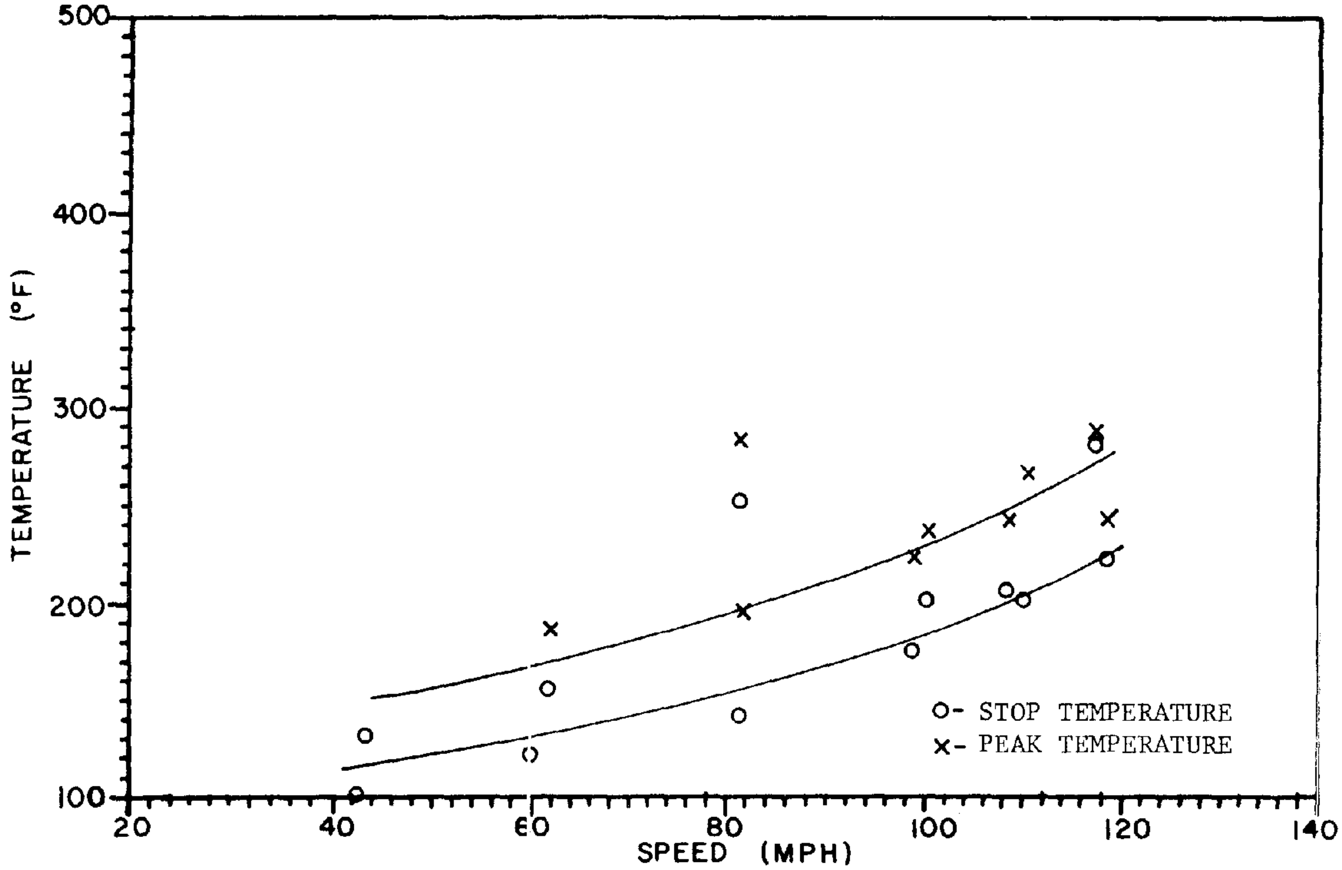

Figure C-6. Car No. 21044 - Full Service Braking, Disc Temperature, (60/40 Disc/Tread Ratio)

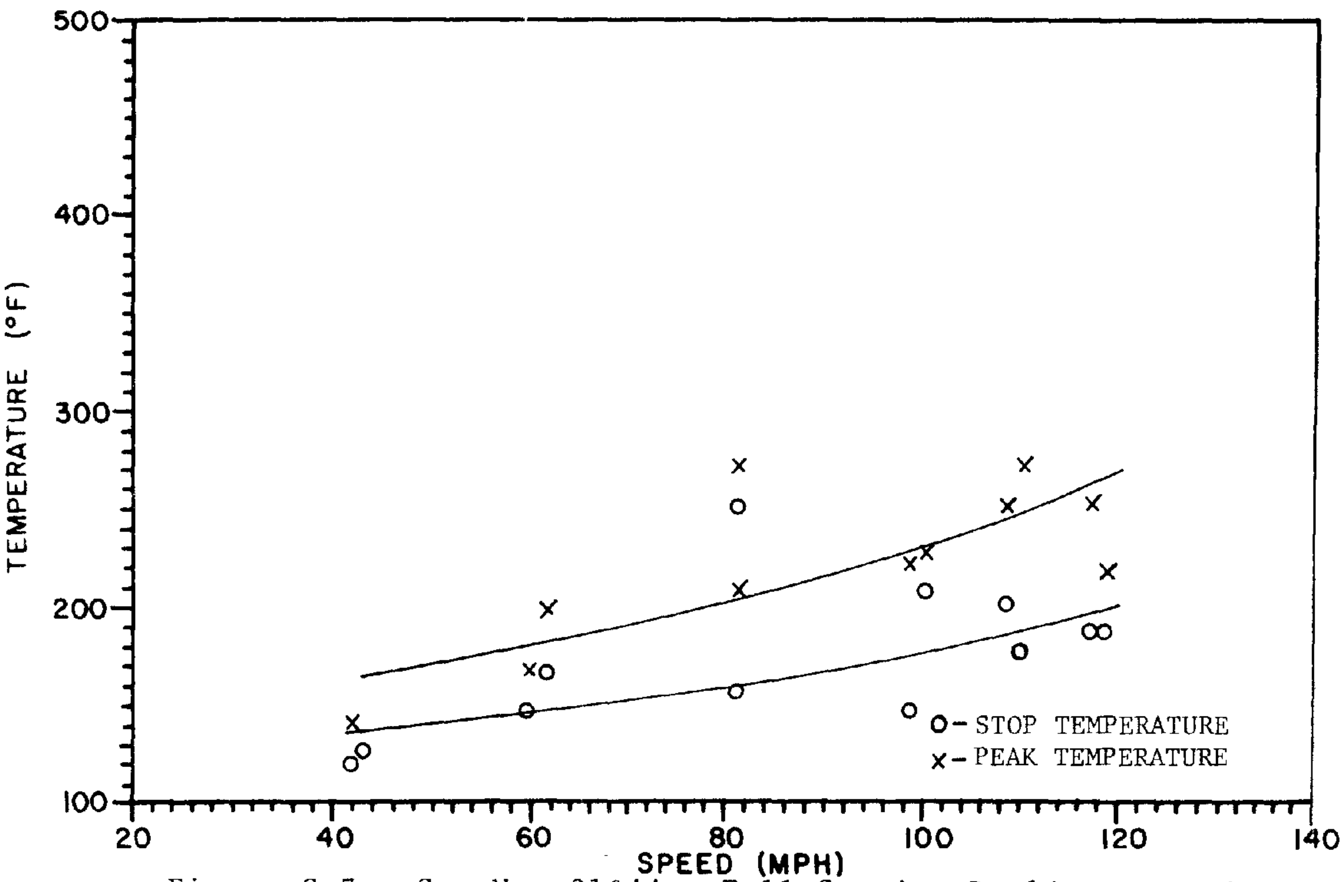

Figure C-7. Car No. 21044 - Full Service Braking, Tread Temperature, (60/40 Disc/Tread Ratio)

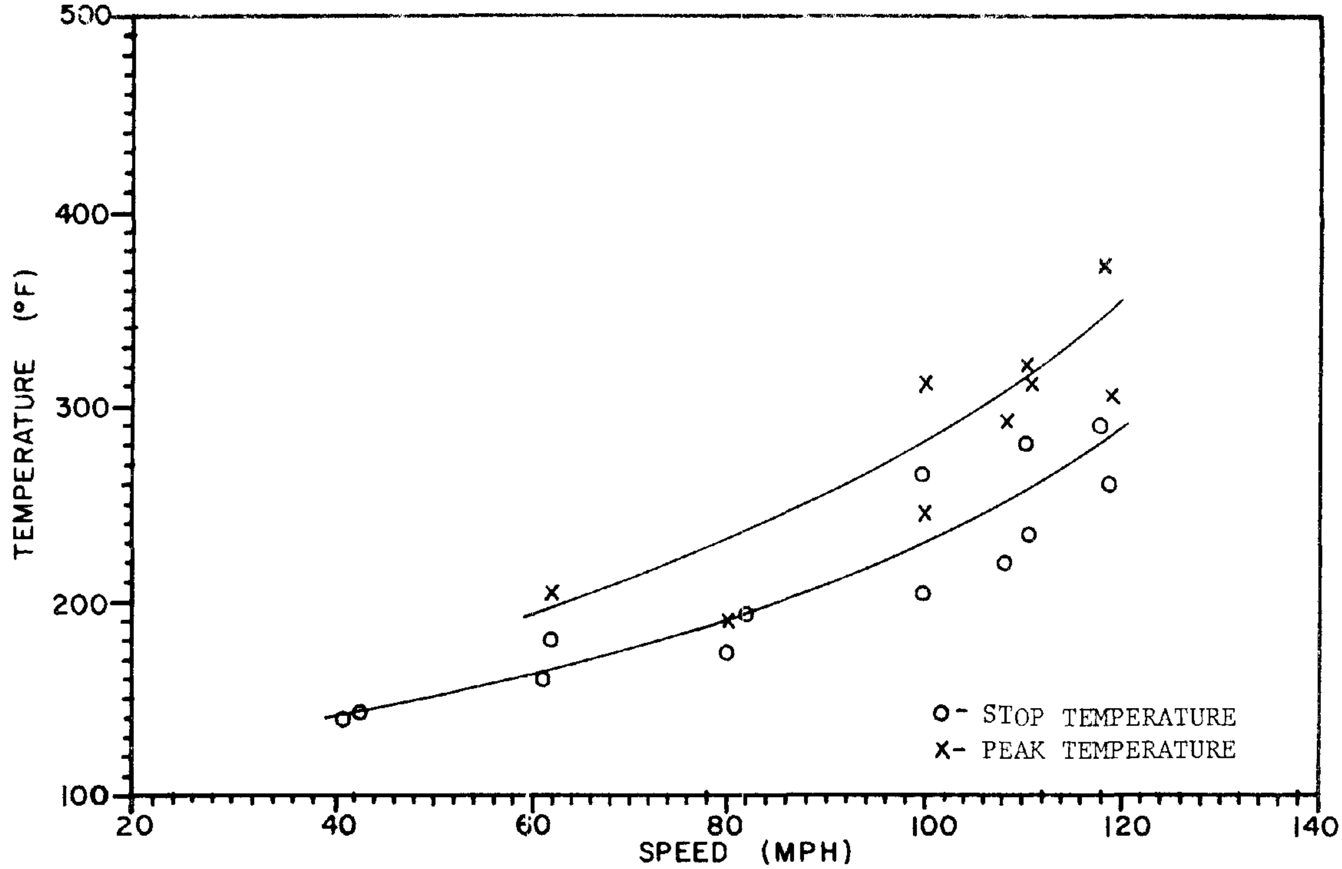

Figure C-8. Car No. 21044 - Emergency Service Braking, Disc Temperature (60/40 Disc/Tread Ratio)

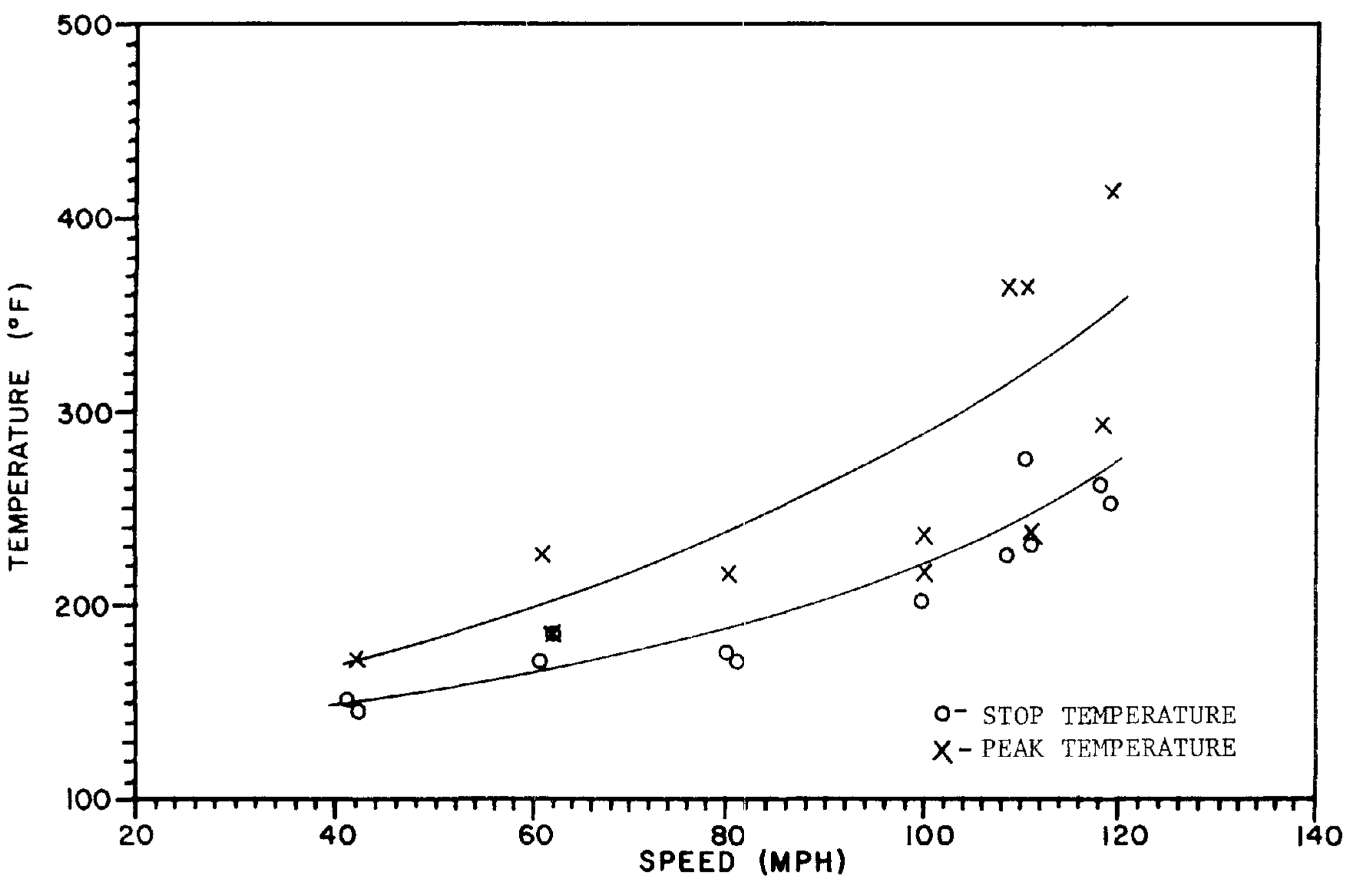

Figure C-9. Car No. 21044 - Emergency Service Braking, Tread Temperature (60/40 Disc/Tread Ratio)

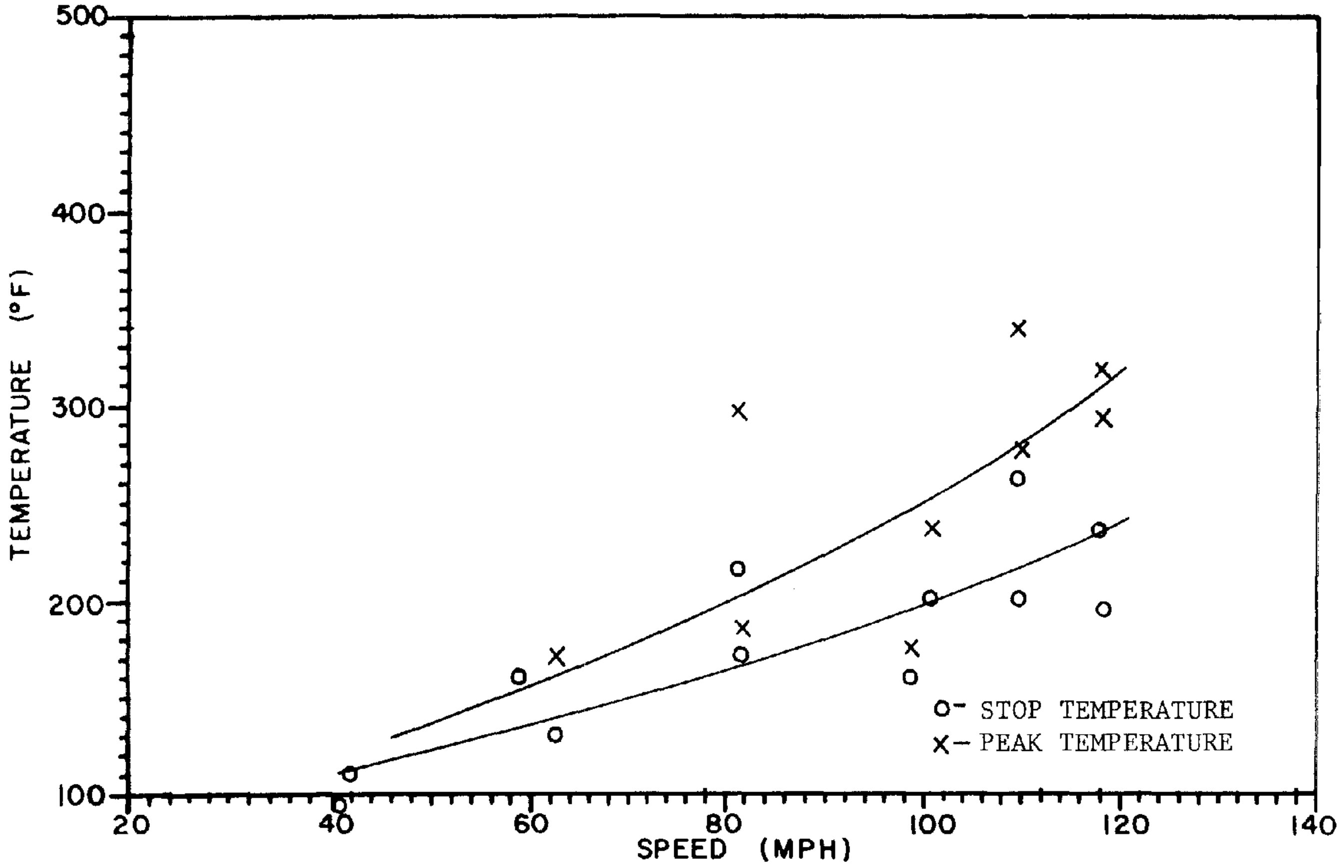

Figure C-10. Car No. 21044 - Emergency Service Braking, Disc Temperature, (50/50 Disc/Tread Ratio)

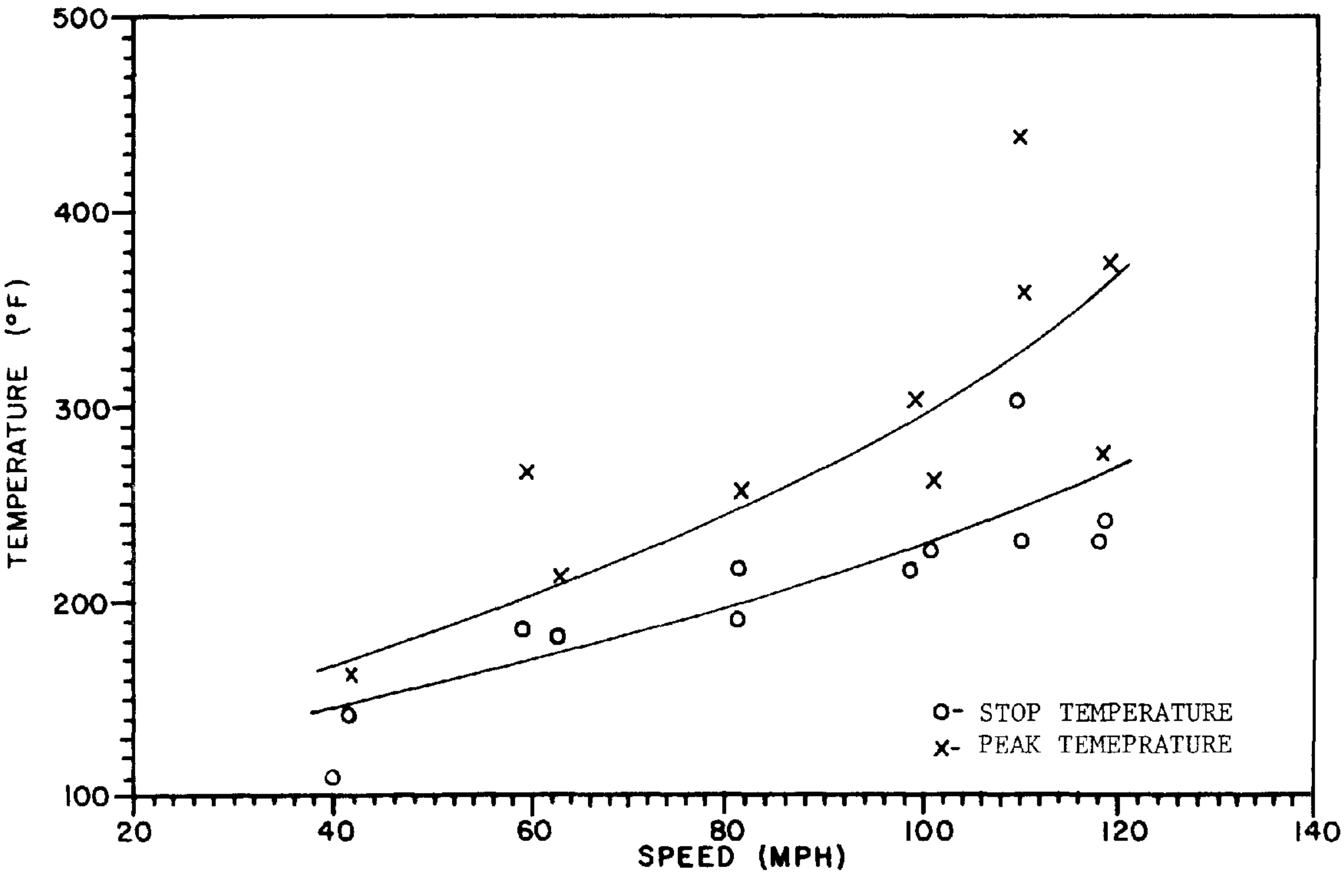

Figure C-11. Car No. 21044 - Emergency Service Braking, Tread Temperature (50/50 Disc/Tread Ratio)

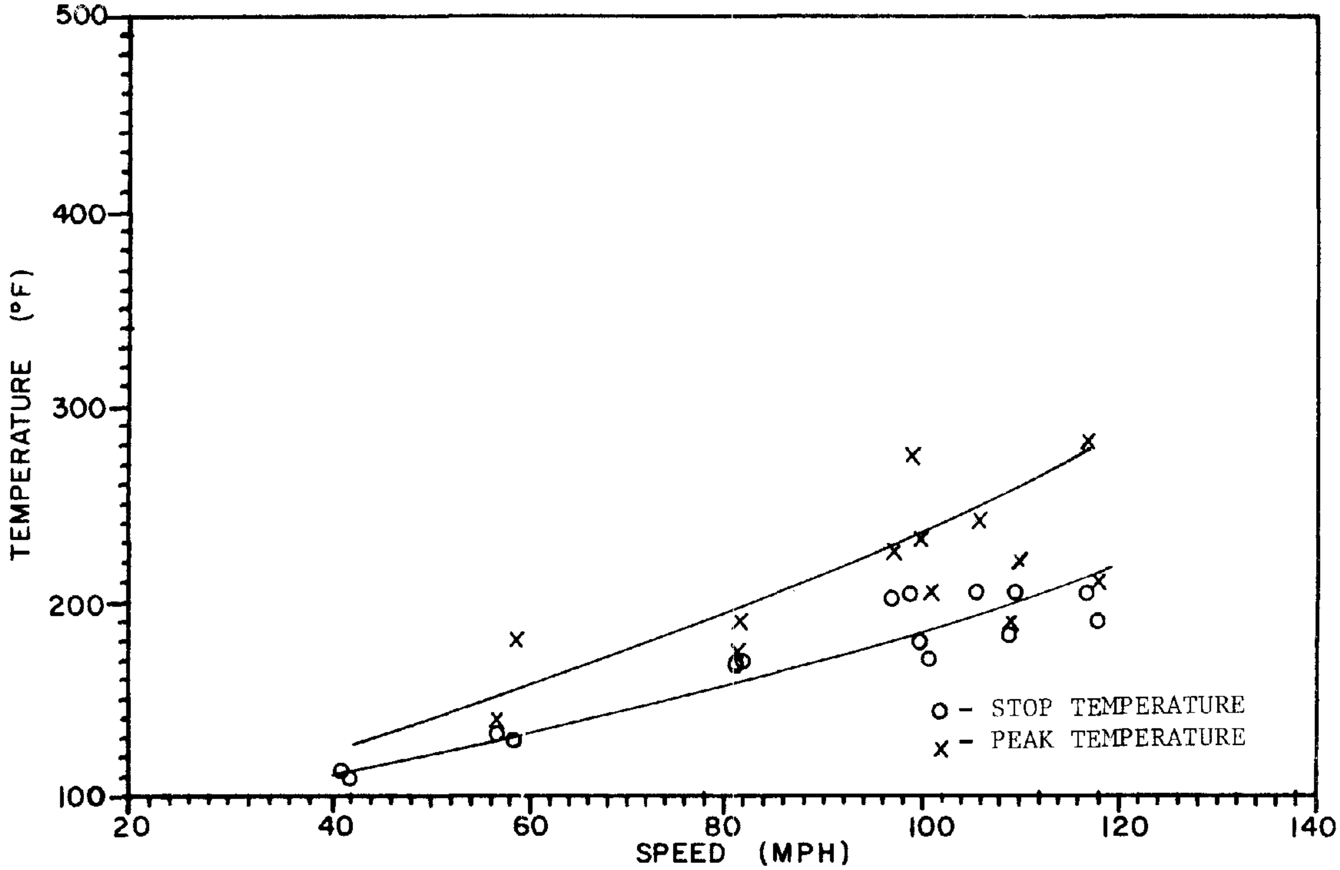

Figure C-12. Car No. 21063 - Full Service Braking, Disc Temperature (50/50 Disc/Tread Ratio)

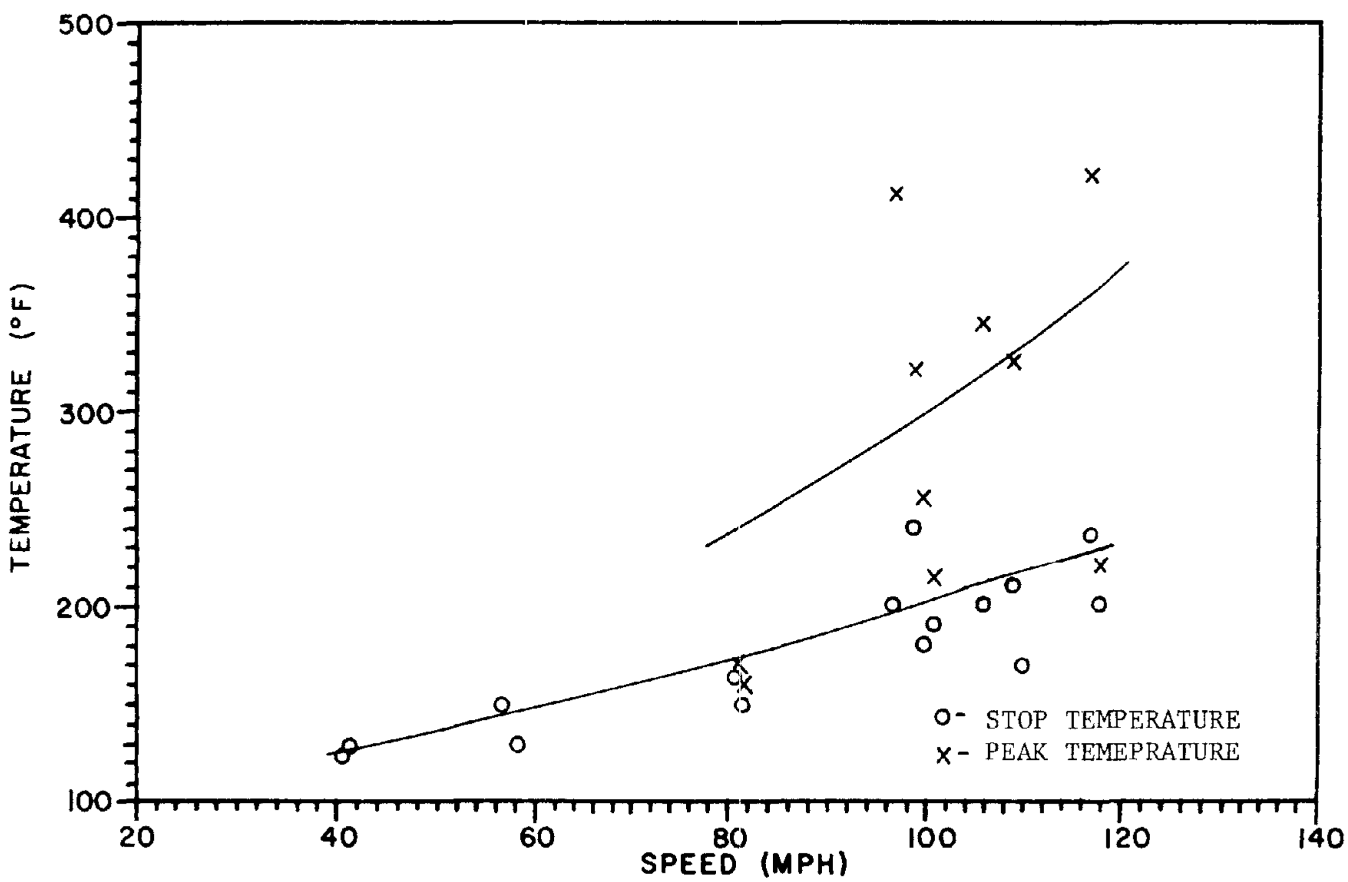

Figure C-13. Car No. 21063 - Full Service Braking, Tread Temperature (50/50 Disc/Tread Ratio)

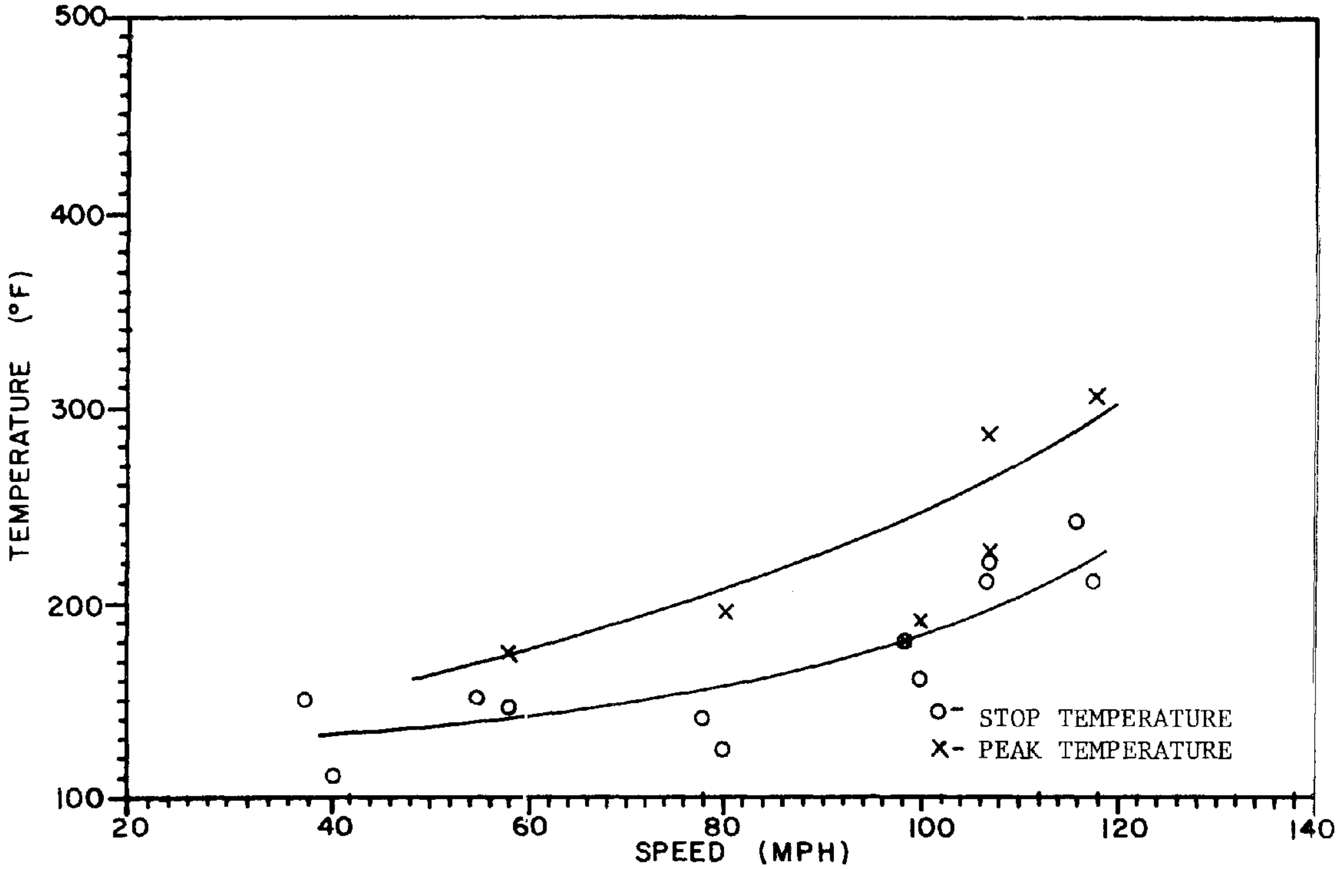

Figure C-14. Car No. 21063 - Full Service Braking, Disc Temperature (60/40 Disc/Tread Ratio)

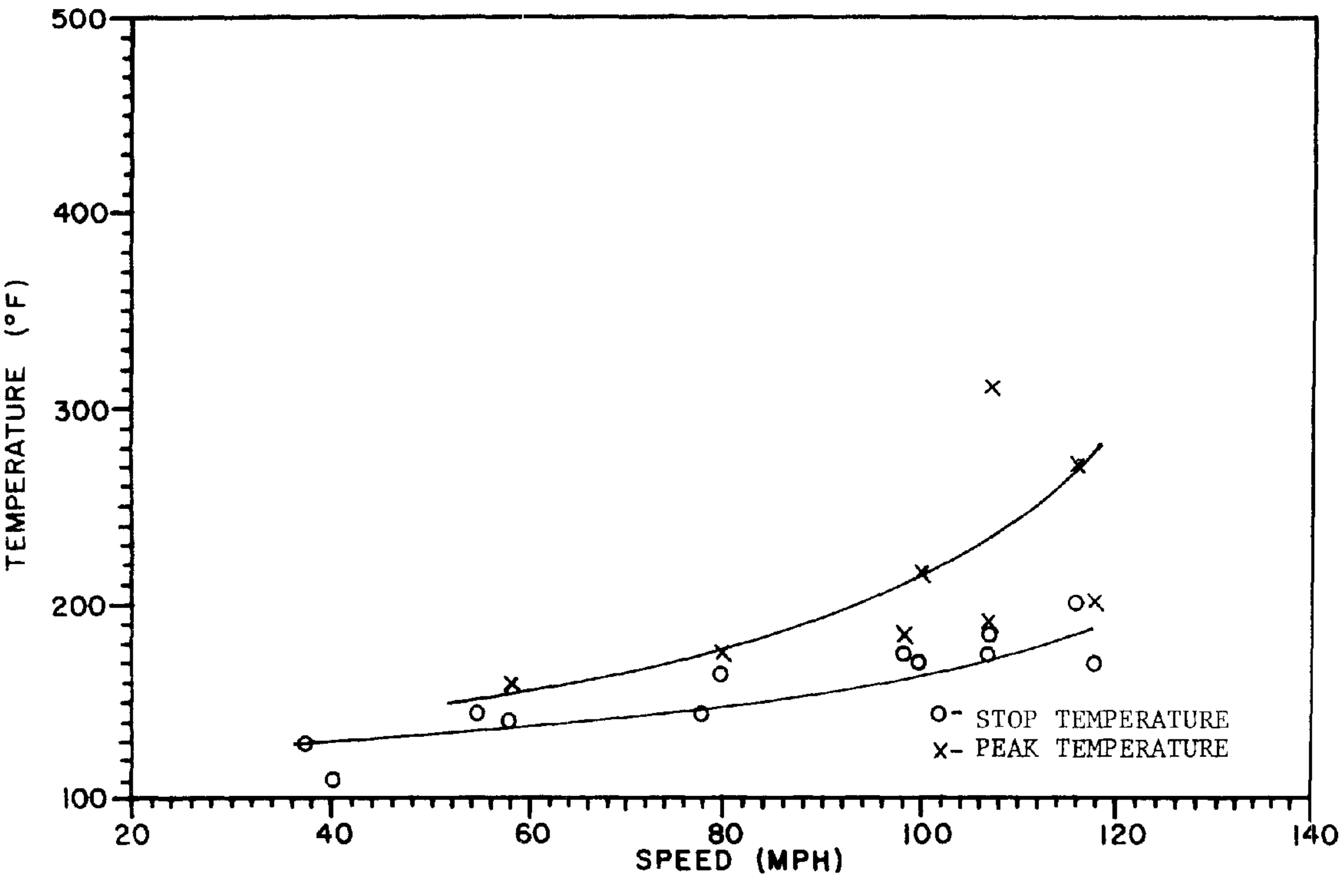

Figure C-15. Car No. 21063 - Full Service Braking, Tread Temperature (60/40 Disc/Tread Ratio)

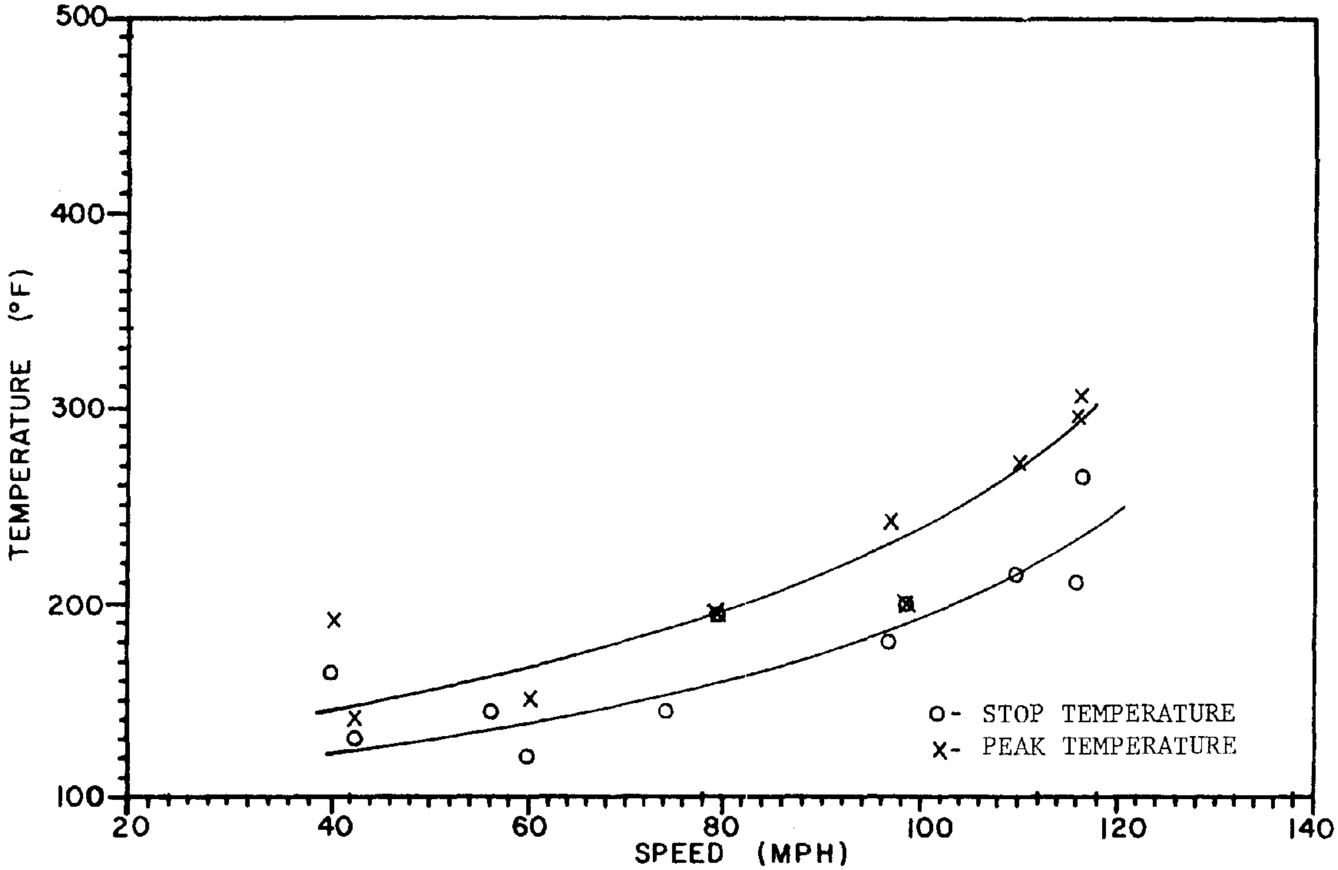

Figure C-16. Car No. 21063 - Emergency Service Braking, Disc Temperature (50/50 Disc/Tread Ratio)

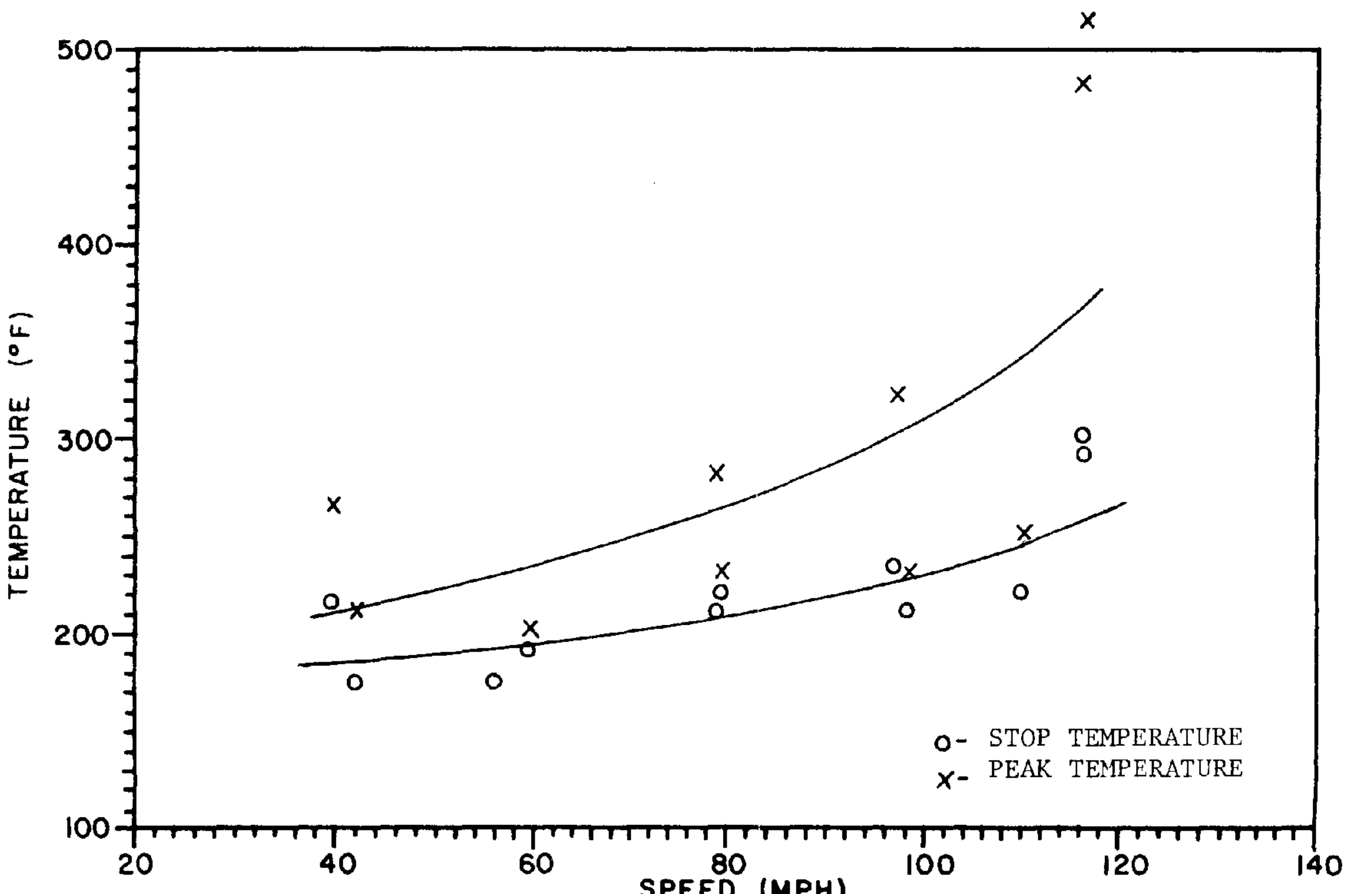

Figure C-17. Car No. 21063 - Emergency Service Braking, Tread Temperature (50/50 Disc/Tread Ratio)

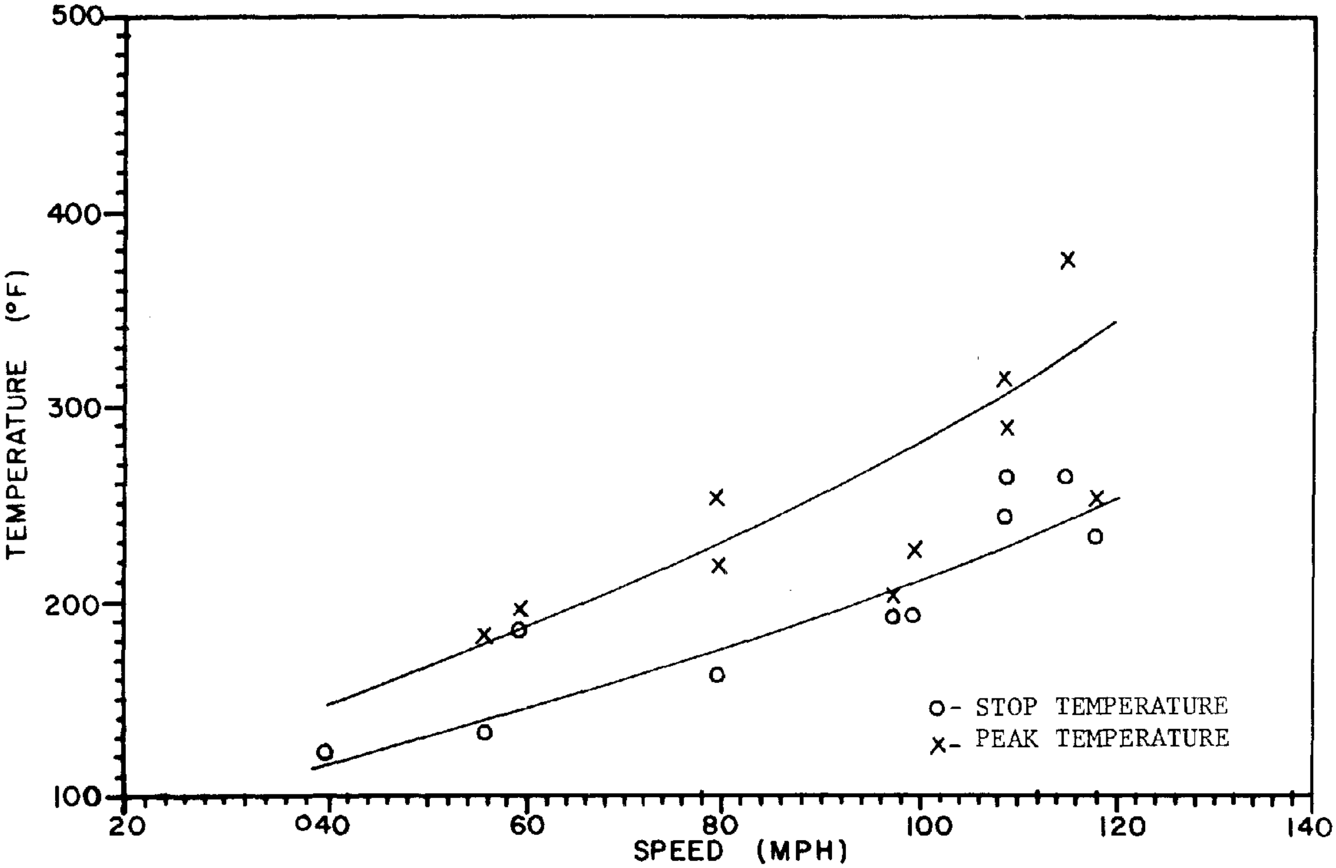

Figure C-18. Car No. 21063 - Emergency Service Braking, Disc Temperature (60/40 Disc/Tread Ratio)

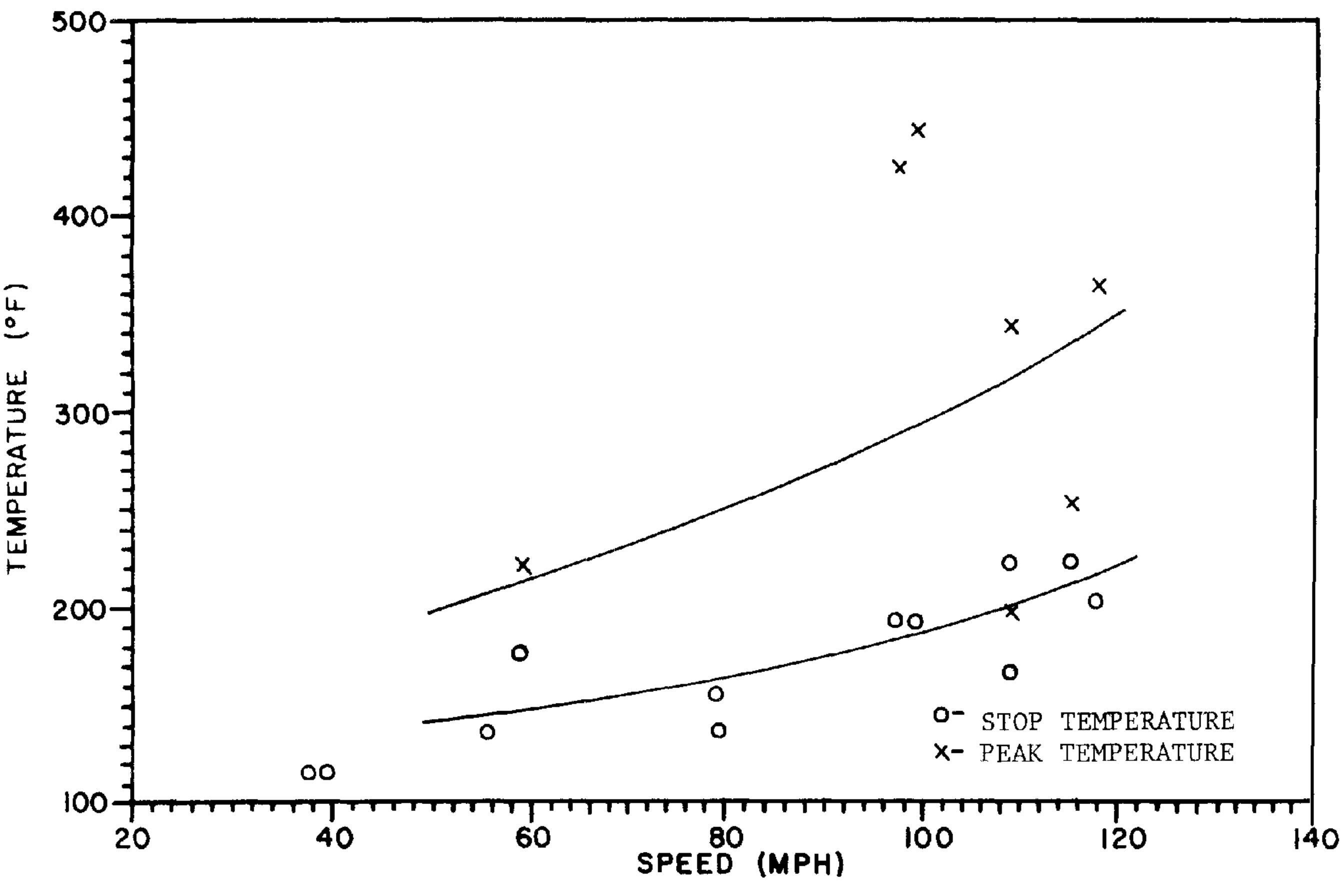

Figure C-19. Car No. 21063 - Emergency Service Braking, Tread Temperature (60/40 Disc/Tread Ratio)

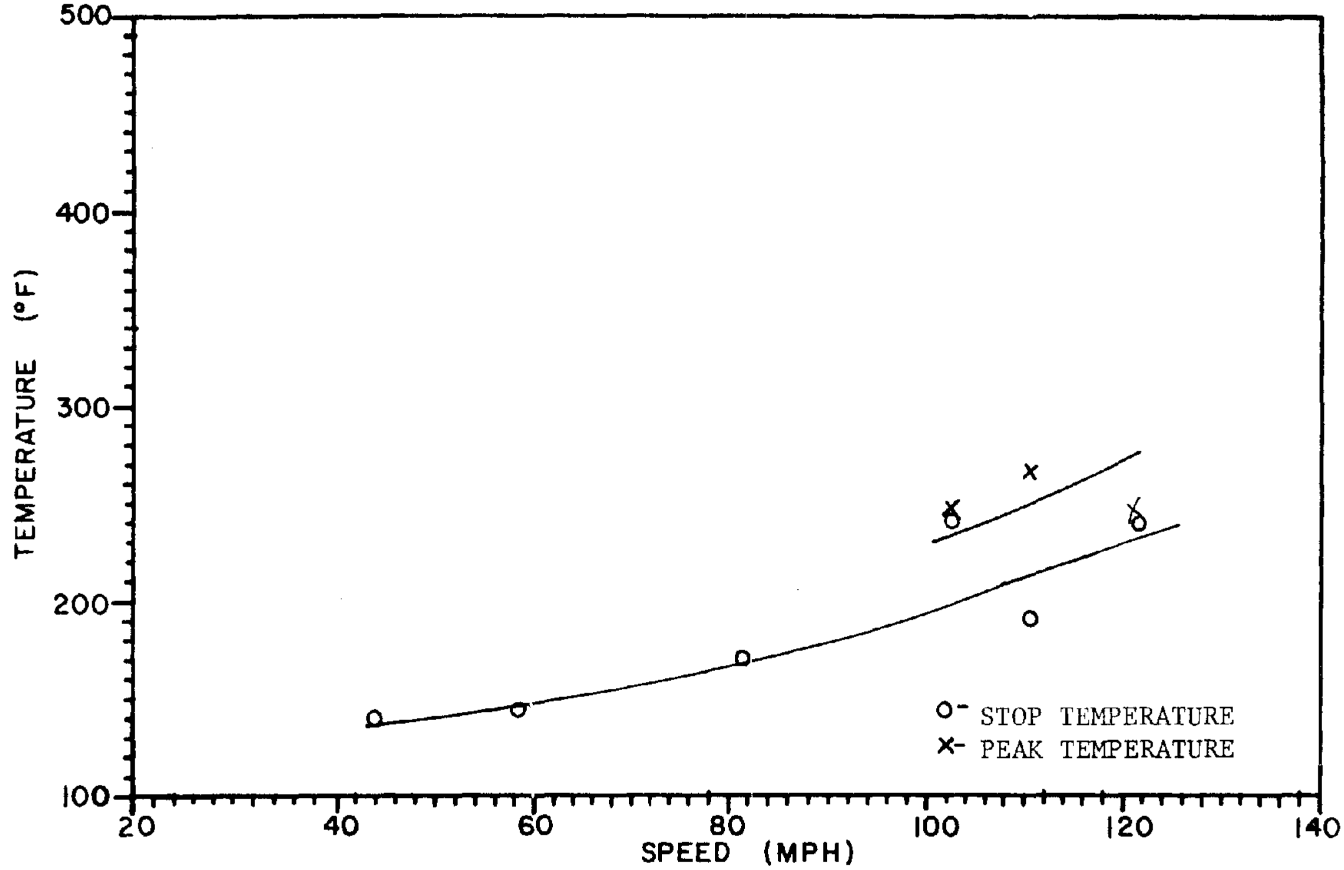

Figure C-20. Car No. 21087 - Full Service Braking, Disc Temperature (60/40 Disc/Tread Ratio)

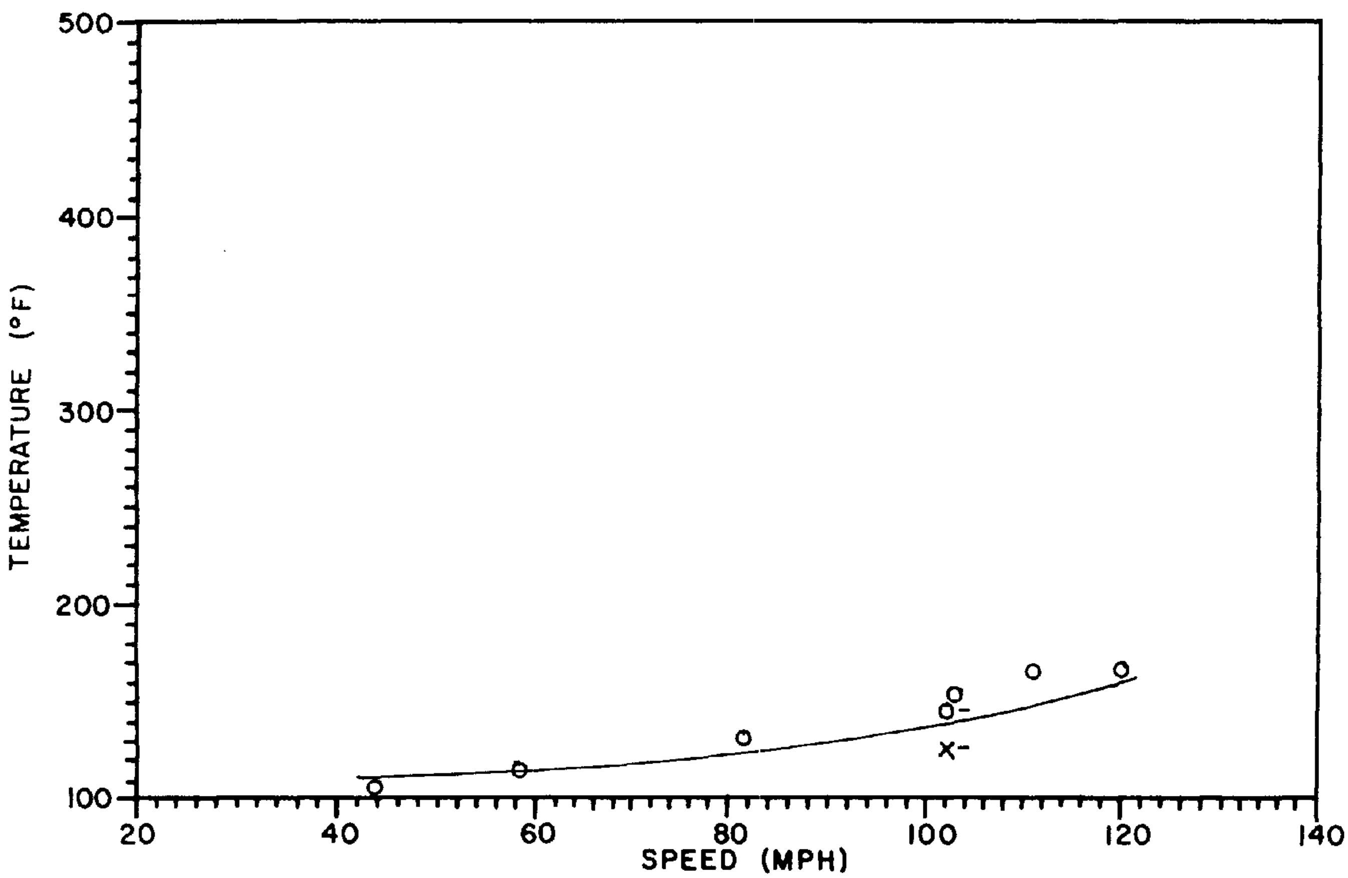

Figure C-21. Car No. 21087 - Full Service Braking, Tread Temperature (60/40 Disc/Tread Ratio)

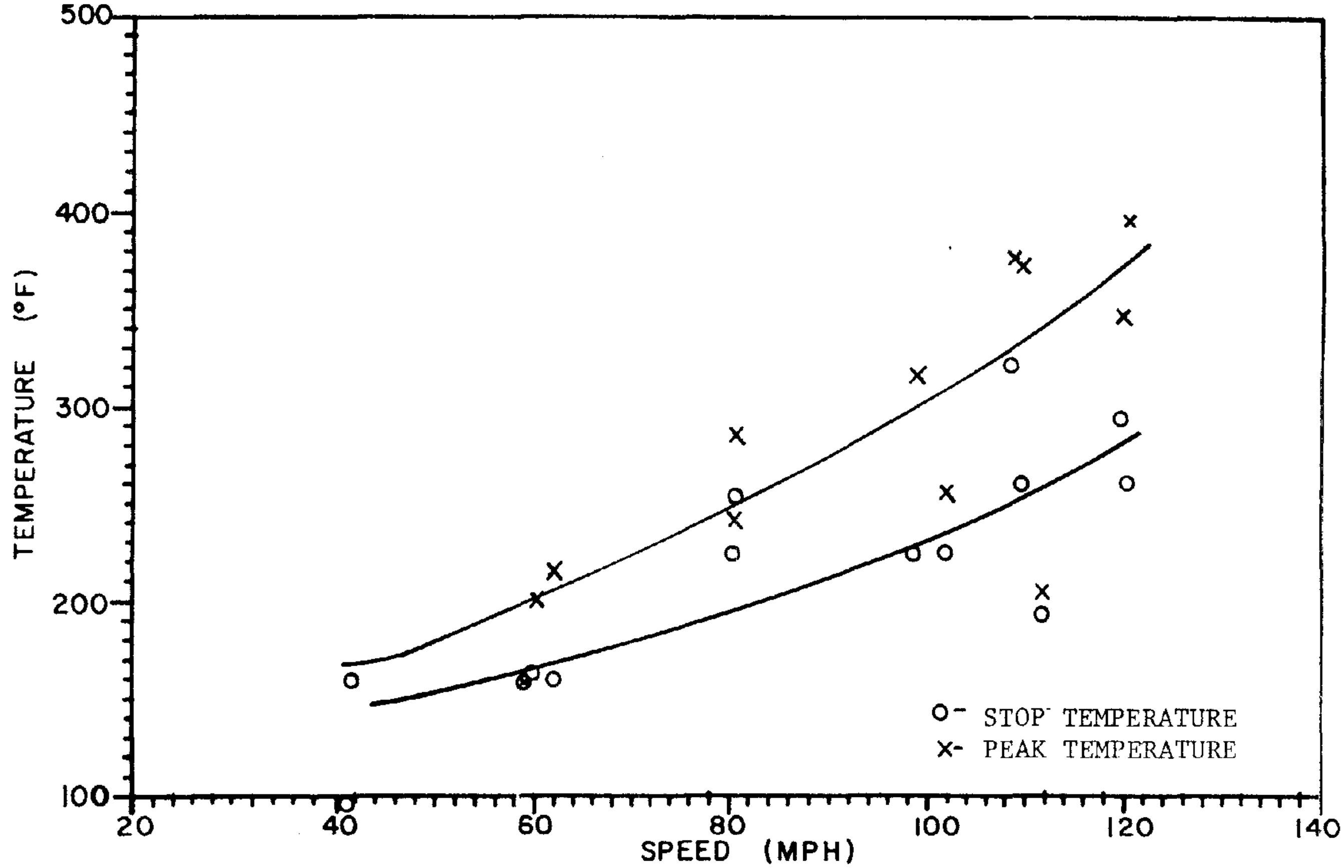

Figure C-22. Car No. 21087 - Full Service Braking, Disc Temperature (70/30 Disc/Tread Ratio)

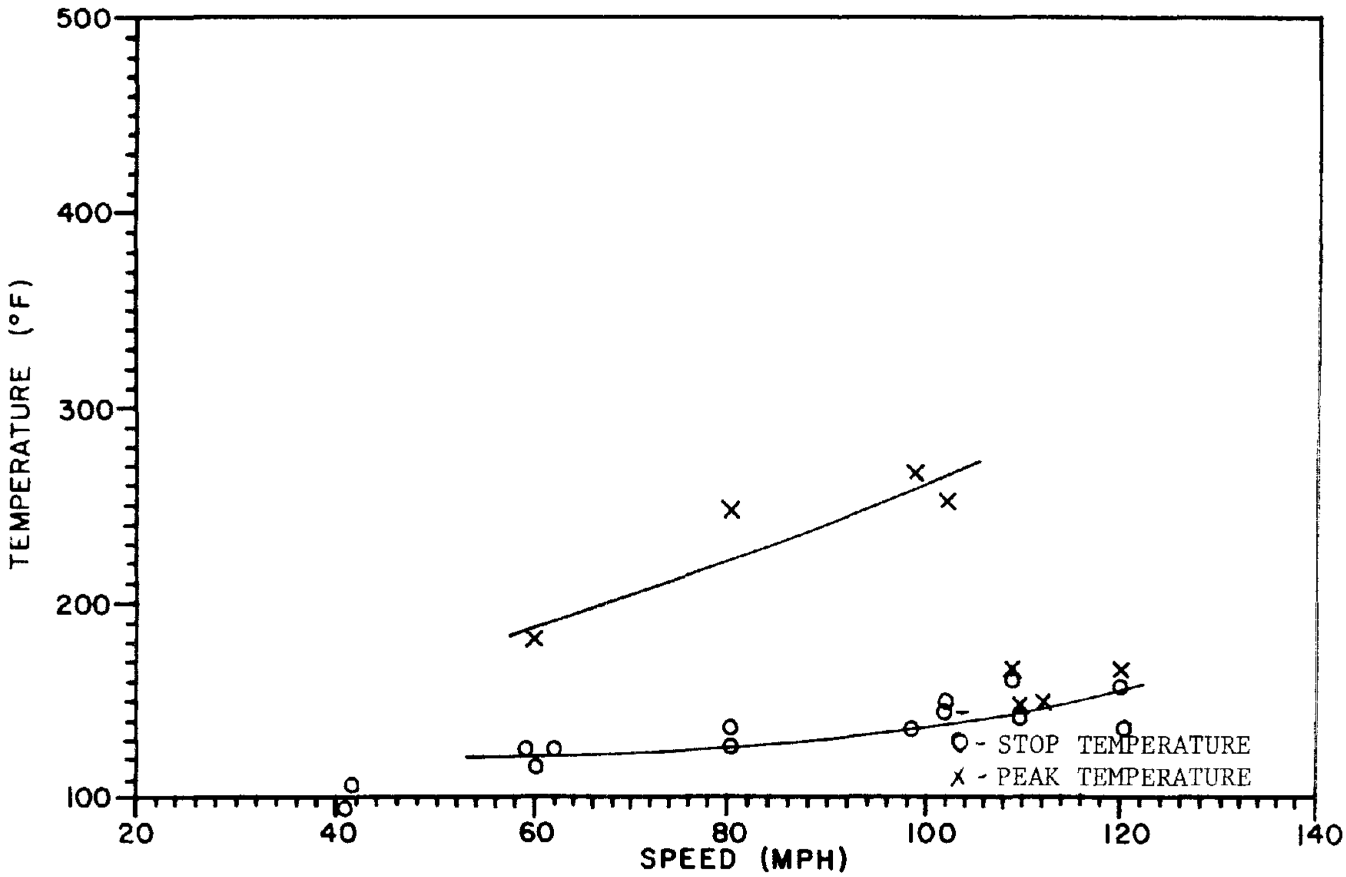

Figure C-23. Car No. 21087 - Full Service Braking, Tread Temperature (70/30 Disc/Tread Ratio)

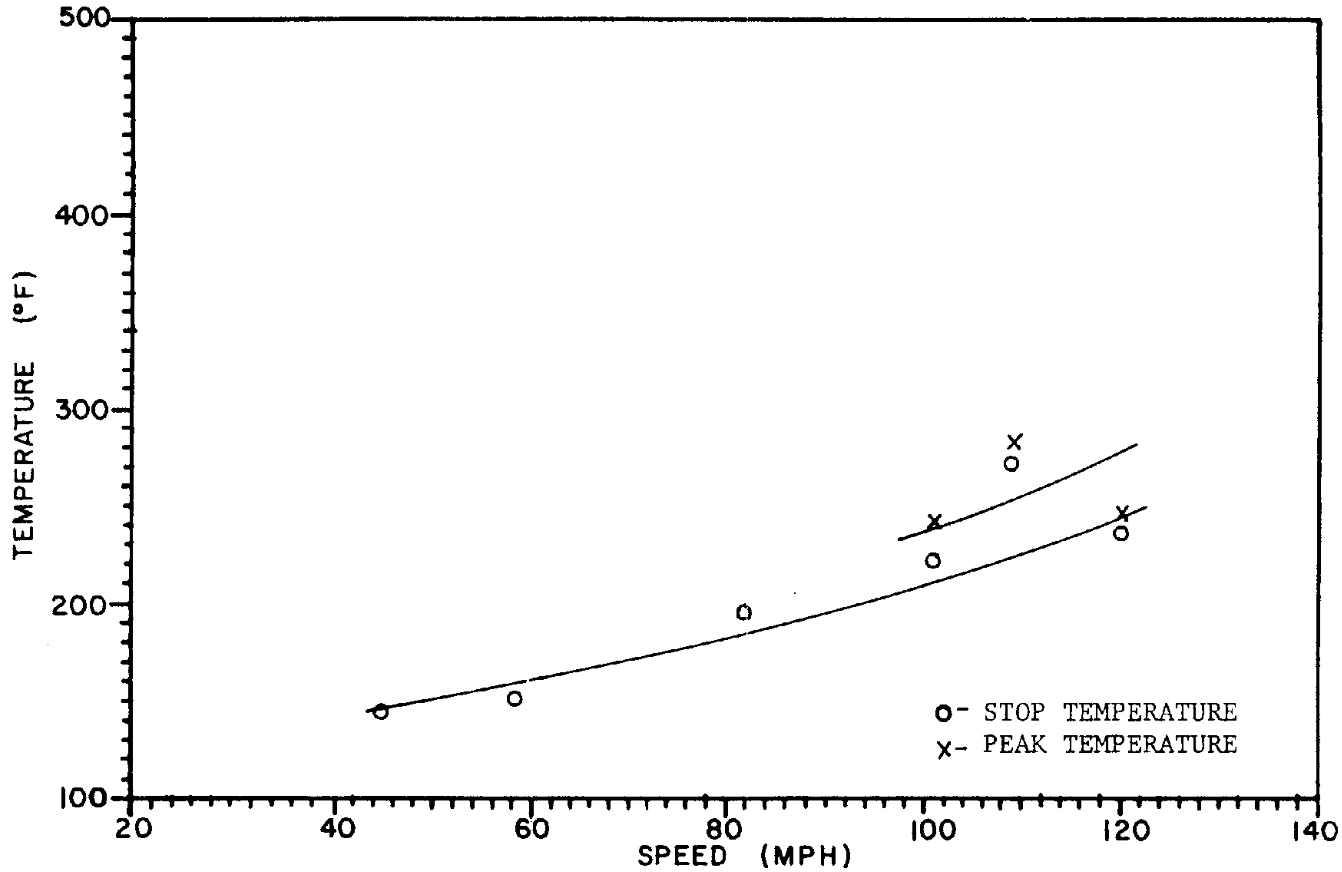

Figure C-24. Car No. 21087 - Emergency Service Braking, Disc Temperature (60/40 Disc/Tread Ratio)

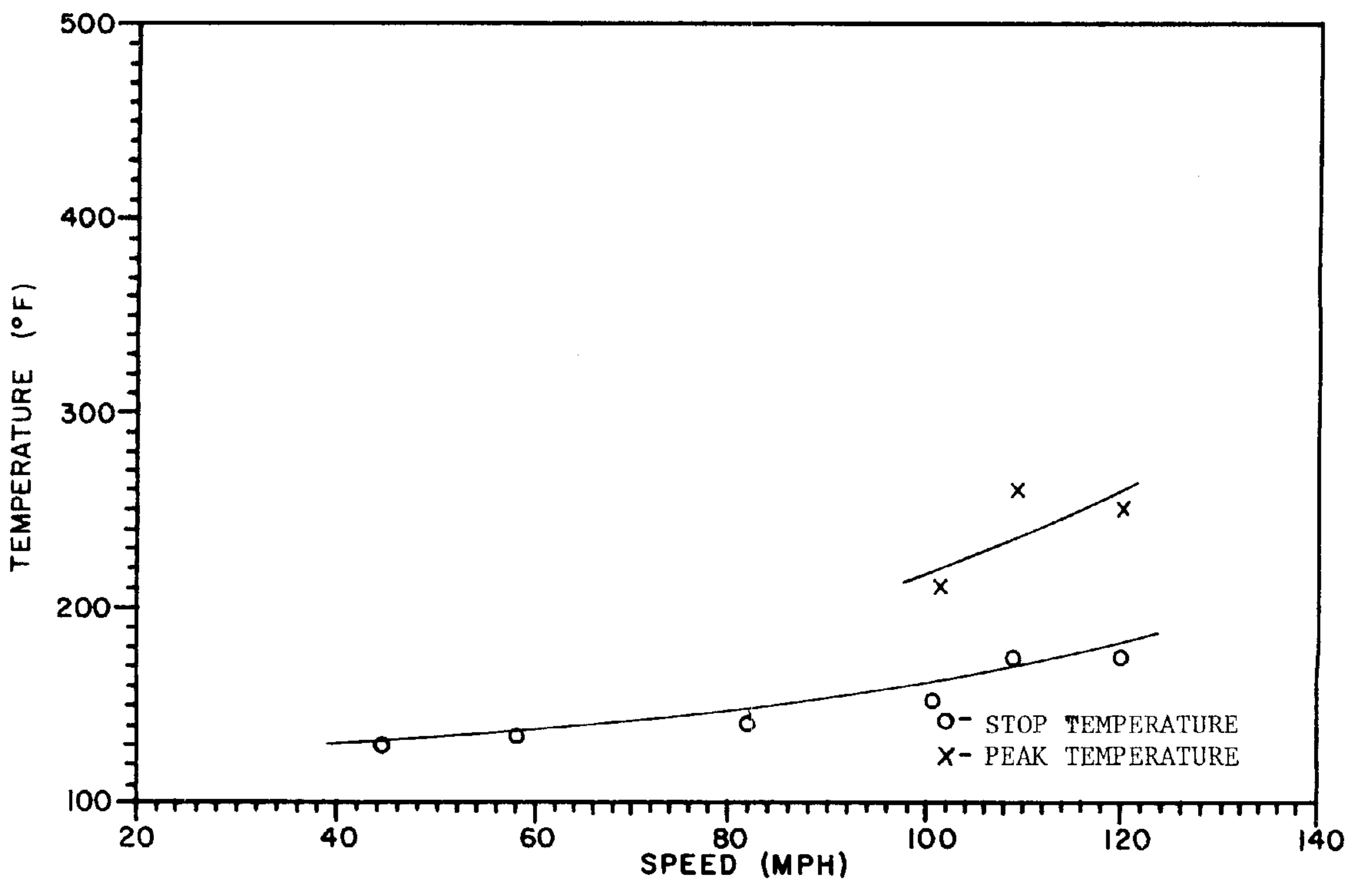

Figure C-25. Car No. 21087 - Emergency Service Braking - Tread Temperature (60/40 Disc Tread Ratio)

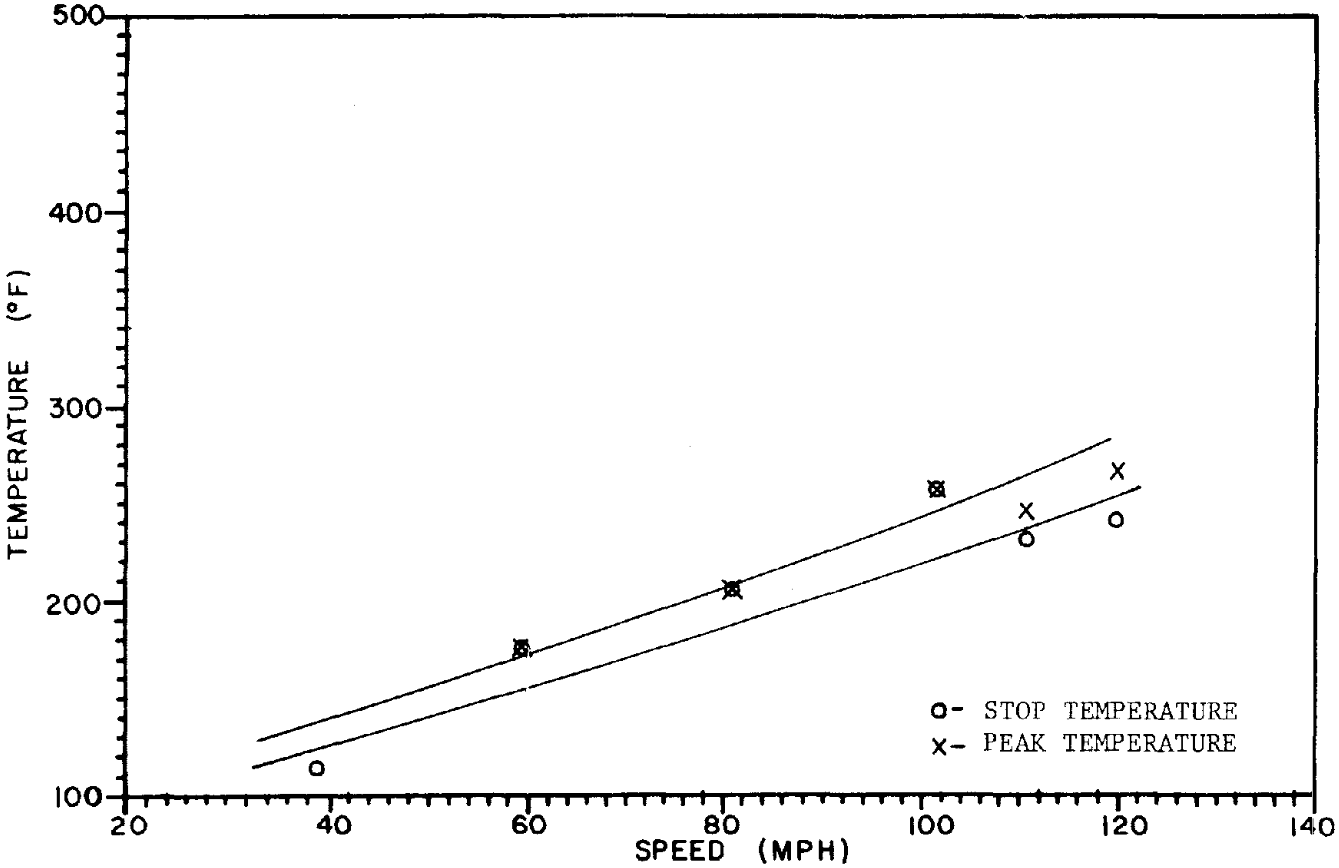

Figure C-26. Car No. 21087 - Emergency Service Braking, Disc Temperature (70/30 Disc/Tread Ratio)

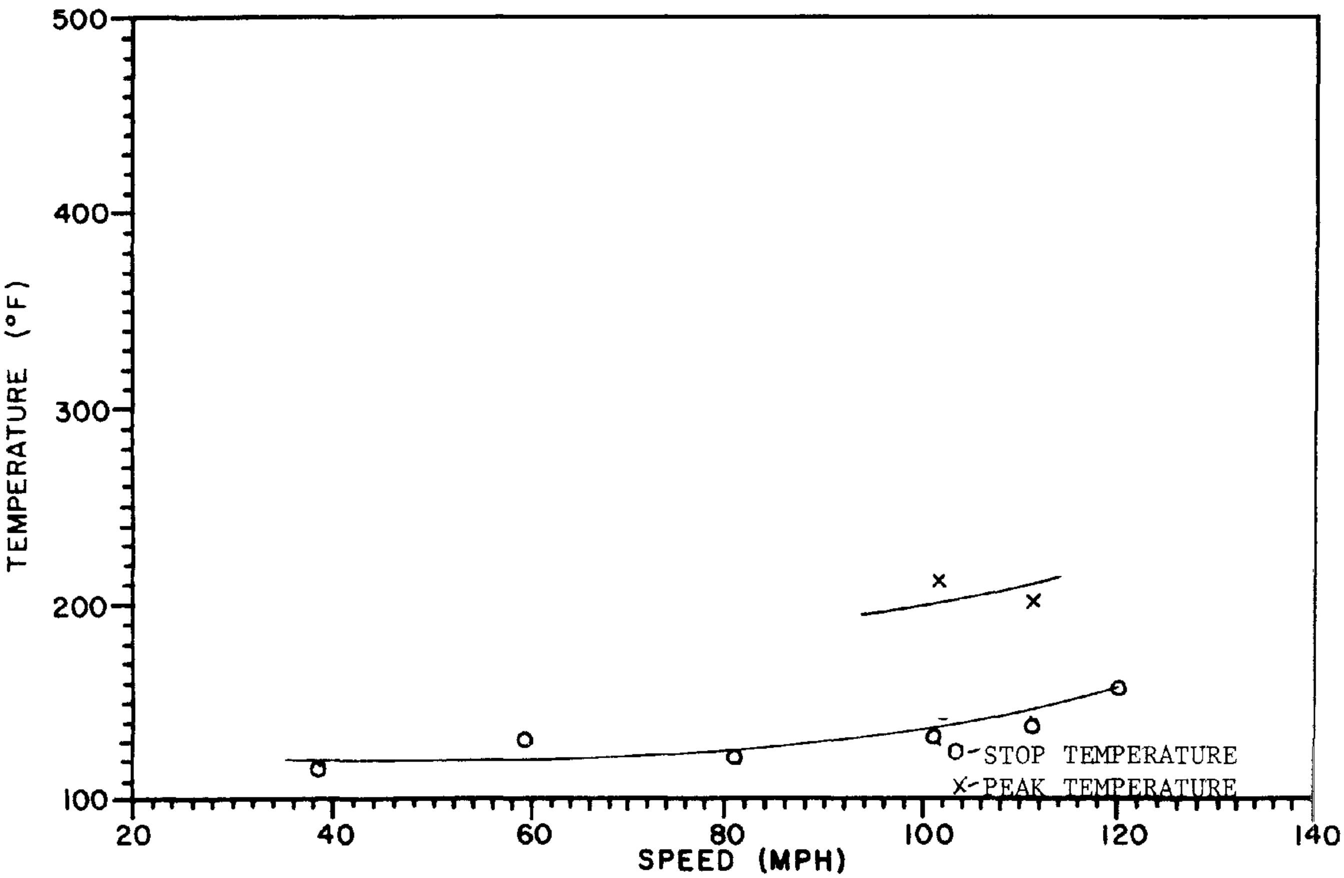

Figure C-27. Car No. 21087 - Emergency Service Braking, Tread Temperatures, (70/30 Disc/Tread Ratio)

APPENDIX D

DECELERATION DATA

INDIVIDUAL TEST RUNS

NOTE: DATA IS PRESENTED IN THE FOLLOWING ORDER:

Car Number
Brake Service
Test Number

TABLE D-1

21018/STANDARD	HALF-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112702	87 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	86.0	1.42	
37.24	33.0	1.82	
49.58	10.5	2.05	
54.7	0.0		

TABLE D-2

21018/STANDARD	HALF-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112703	103 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	102.0	1.46	
37.8	46.8	1.73	
48.0	29.2	1.94	
57.6	10.6	2.00	
62.9	0.0		

TABLE D-3

21018/STANDARD	HALF-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112704	67 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	66.5	1.40	
15.4	45.0	1.72	
32.0	16.5	2.06	
40.0			

TABLE D-4

21018/STANDARD	HALF - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112705	114 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	113.0	1.43	
53.1	37.2	1.9	
66.2	12.5	2.27	
71.7	0.0		

TABLE D-5

21018/STANDARD	HALF-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112706	46 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	44.5	1.35	
9.75	31.5	1.84	
26.9	0.0		

TABLE D-6

21018/STANDARD	HALF-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112707	118.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	117.5	1.58	
9.2	103.0	1.43	
51.4	43.5	1.68	
65.1	19.5	2.29	
73.6	0.0		

TABLE D-7

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO
112801	82.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	81.0	2.02	
16.8	47.0	2.42	
25.9	25.0	3.28	
32.3	4.0	--	B TRUCK 0.2 SEC.
33.9	0.0		

TABLE D-8

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112802	103 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	101.5	1.96	
27.8	47.0	2.30	
36.5	27.0	2.84	
41.6	12.5	3.47	
45.2	0.0		

TABLE D-9

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112803	68 mph	+1.0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	62.0	1.5	
2.3	58.5	2.1	
8.1	46.5	2.6	
16.9	23.5	3.2	
21.0	10.5	3.6	
23.9	0.0		

TABLE D-10

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112804	113 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	111.0	1.98	
8.6	94.0	1.95	
26.55	59.0	2.04	
37.8	36.0	2.54	
44.5	19.0	3.39	
50.1	0.0		

TABLE D-11

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112805	45 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	44.5	1.68	
2.5	40.3	2.63	
6.8	29.0	2.90	
9.9	20.0	3.57	
15.5	0.0		

TABLE D-12

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112806	124 mph	+1
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	122.5	2.0	
27.9	65.6	2.0	
41.8	37.5	2.5	
47.8	22.5	3.2	
54.9	0.0		

TABLE D-13

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112903	8.35 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	82.5	2.12	
17.9	44.5	2.65	
26.0	23.0	3.19	
33.2	0.0		

TABLE D-14

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112904	100 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	99.0	2.10	
22.6	51.5	2.68	
33.8	21.5	3.39	
36.9	11.0	--	A TRUCK 0.4 SEC.
37.8	8.5	3.04	
40.6	0.0		

TABLE D-15

21018/STANDARD	FULL-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112905	44 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	43.0	2.1	
3.6	35.5	2.6	
8.7	22.0	3.1	
12.3	11.0	3.1	
15.8	0.0		

TABLE D-16

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO
112906	117 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	116.0	2.09	
33.9	45.0	2.39	
42.9	23.5	3.05	
47.0	11.0	3.67	
50.0	0.0		

TABLE D-17

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112907	64 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	63.0	1.88	
1.7	59.8	2.44	
9.8	40.0	2.75	
14.9	26.0	3.17	
19.0	13.0	3.71	
22.5	0.0		

TABLE D-18

21018/STANDARD	FULL - 68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112908	107.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	106.0	2.07	
29.4	45.0	2.50	
38.0	23.5	2.93	
42.6	10.0	3.57	
45.4	0.0		

TABLE D-19

21018/STANDARD	EMERGENCY-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO
112807	84 mph	+1
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	82.0	2.55	
14.9	44.0	3.11	
21.0	25.0	3.90	
25.1	9.0	--	B TRUCK 0.7 SEC
26.7	4.0	--	A TRUCK 0.25 SEC
28.3	0.0		

TABLE D-20

21018/STANDARD	EMERGENCY-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112808	102.5 mph	+0.5
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	101.0	2.53	
8.5	80.0	2.53	
22.33	45.0	2.93	
27.62	29.5	--	A TRUCK 0.85 SEC
29.80	24.0	3.82	
33.60	9.5	--	A&B TRUCK 0.7 SEC
37.1	0.0		

TABLE D-21

21018/STANDARD	EMERGENCY-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112810	109 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	107.0	2.43	
24.28	48.0	2.93	
31.90	25.7	3.81	
36.81	7.0	--	B TRUCK 0.7 SEC
39.0	0.0		

TABLE D-22

21018/STANDARD	EMERGENCY-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112901	42 mph	+2
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	41.5	--	
1.51	37.0	3.50	
6.17	20.7	4.40	
8.60	10.0	--	B TRUCK 0.9 SEC
10.34	4.0	--	A TRUCK 0.4 SEC
12.0	0.0		

TABLE D-23

21018/STANDARD	EMERGENCY-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

112902	119 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	117.5	2.70	
6.86	99.0	2.50	
29.86	41.5	2.79	
36.50	23.0	--	A TRUCK 0.85 SEC
39.0	16.7	3.70	
41.57	7.2	--	A&B TRUCK 0.6 SEC
44.5	0.0		

TABLE D-24

21018/STANDARD	EMERGENCY-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

120303	63 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	61.5	--	
1.0	60.0	3.26	
10.60	28.7	4.02	
15.38	9.5	--	A&B TRUCKS 0.5 SEC
18.1	0.0		

TABLE D-25

21018/STANDARD	EMERGENCY-68 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020513	118 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	116.0	2.54	
10.61	89.0	2.43	
26.25	51.0	2.69	
35.82	25.3	3.38	
43.3	0.0		

TABLE D-26

21018/STANDARD	FULL - 55PSI	
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO
020501	110	+1
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	108.5	2.1	
10.0	89.0	1.85	
33.5	45.0	2.1	
42.8	26.0	2.4	
53.2	0.0		

TABLE D-27

21018/STANDARD	FULL - 55 PSI	
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020502	82	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	81.0	2.15	
25.5	25.0	2.70	
34.2			

TABLE D-28

21018/STANDARD	FULL - 55 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020503	101	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	100.0	2.1	
8.9	61.5	1.9	
27.6	45.5	2.2	
38.1	22.0	2.8	
46.0			

TABLE D-29

21018/STANDARD	FULL - 55PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020504	41.5	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	41.0	1.8	
2.3	38.0	2.3	
8.3	24.0	2.6	
11.8	15.5	2.8	
17.4	0.0		

TABLE D-30

21018/STANDARD	FULL - 55 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020506	119.5	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	118.5	2.1	
7.1	104.5	1.9	
16.2	88.5	1.8	
33.8	57.0	2.1	
45.3	34.0	2.2	
50.8	22.0	2.6	
59.5	0.0		

TABLE D-31

21018/ STANDARD	FULL - 55 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020507	41	
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	40.5	2.0	
3.3	34.0	2.4	
8.3	23.0	2.6	
17.1	0.0		

TABLE D-32

21018/STANDARD	FULL - 55 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020508	110	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	109.0	2.1	
7.1	96.0	1.8	
31.7	52.0	2.0	
38.7	38.0	2.2	
43.2	28.0	2.6	
49.8	11.0	2.7	
54.0	0.0		

TABLE D-33

21018/STANDARD	FULL - 55 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020509	82	B
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	81.0	2.0	
14.9	52.5	2.4	
25.9	27.0	2.6	
30.9	14.0	2.7	
35.4			

TABLE D-34

21018/STANDARD	FULL - 55 PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020510	99	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	98.0	2.1	
12.7	73.0	1.9	
23.6	53.5	2.1	
32.8	34.0	2.3	
37.1	24.5	2.7	
46.2			

TABLE D-35

21018/STANDARD	FULL - 55PSI	N/A
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

020511	119	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	117.5	2.1	
7.7	103.0	1.8	
23.3	75.0	1.8	
39.4	47.0	2.0	
43.4	39.0	2.3	
50.7	23.0	2.6	
59.6	0.0		

TABLE D-36

21044/WABCO-DUAL	HALF	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121301	81.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.5	1.28	
30.9	41.0	1.33	
44.4	23.0	1.57	
31.4	12.0	1.79	
58.1	0.0		

TABLE D-37

21044/WABCO=DUAL	HALF	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121304	41 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	40.5	1.22	
14.35	23.0	1.35	
21.4	13.5	1.69	
29.4	0.0		

TABLE D-38

21044/WABCO-DUAL	HALF	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121307	117.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	116.0	1.40	
36.9	64.5	1.44	
58.5	33.5	1.62	
71.5	12.5	1.81	
78.4	0.0		

TABLE D-39

21044/WABCO-DUAL	HALF	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121802	42.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	42.0	0.3	
4.0	41.7	1.11	
22.4	18.0	1.38	
30.4	7.2	1.41	
35.5	0.0		

TABLE D-40

21044/WABCO-DUAL — CAR NO/BRAKE TYPE

HALF — BRAKE SERVICE

60/40 — DISC/TREAD RATIO

121803 — RUN NO.

118 mph — SPEED

0 — SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	117.5	1.38	
10.5	103.0	1.20	
31.0	78.5	1.11	
45.9	62.0	1.21	
83.2	17.0	1.39	
95.4	0.0		

TABLE D-41

21044/WABCO-DUAL	HALF	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121804	81 mph	-0.3
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.5	1.09	
10.0	69.6	0.96	
39.9	40.8	1.14	
57.3	21.3	1.22	
67.8	8.5	1.42	
73.8	0.0		

TABLE D-42

21044/WABCO-DUAL	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121008	79 mph	+1
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	76.5	1.67	
1.8	73.5	2.43	
19.7	30.0	2.54	
26.2	13.5	3.14	
30.5	0.0		

TABLE D-43

21044/WABCO-DUAL	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121010	40 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	39.0	1.55	
1.1	37.3	2.29	
9.1	19.0	2.68	
16.2	0.0		

TABLE D-44

21044/WABCO-DUAL	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121012	59 mph	+2
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	58.0	1.67	
0.9	56.5	2.28	
15.8	22.5	2.70	
20.8	9.0	2.90	
23.9	0.0		

TABLE D-45

21044/WABCO-DUAL	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO
121105	120 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	118.0	2.15	
23.1	64.0	2.50	
37.1	34.0	3.89	
44.1	13.8	3.45	
48.1	0.0		

TABLE D-46

21044/WABCO-DUAL	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121111	100.7 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	99.0	2.10	
16.2	65.0	2.42	
31.7	27.5	2.70	
37.8	11.0	3.24	
41.2	0.0		

TABLE D-47

21044/WABCO-DUAL	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121113	110 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	108.0	2.16	
28.0	47.5	2.65	
39.5	17.0	3.09	
45.0	0.0		

TABLE D-48

21044/WABCO-DUAL	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121201	81.5 mph	
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.5	2.81	
12.8	44.5	3.23	
19.3	23.5	3.92	
25.3	0.0		B TRUCK 3 MPH 0.05 SEC

TABLE D-49

21044/WABCO-DUAL	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121202	101 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	100.0	2.7	
18.1	51.5	3.3	
26.1	25.3	3.8	
29.2	13.5	--	B TRUCK 0.9 SEC
31.7	6.0	--	A TRUCK 0.7 SEC
33.7	0.0		

TABLE D-50

21044/WABCO-DUAL	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121203	61.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	61.5	1.88	
0.8	60.0	2.82	
6.3	44.5	3.24	
15.4	15.0	3.95	
19.2	0.0		

TABLE D-51

21044/WABCO-DUAL	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121205	40.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	39.5	2.14	
0.7	38.0	2.78	
5.2	25.5	3.27	
10.25	9.0	3.40	
12.9	0.0		

TABLE D-52

21044/WABCO-DUAL	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121208	100 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	99.0	2.70	
13.9	61.5	2.83	
19.9	44.5	3.25	
25.9	25.0	3.67	
28.9	14.0	4.24	
32.2	0.0		

TABLE D-53

21044/WABCO-DUAL	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121210	118 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	116.5	2.67	
23.8	53.0	3.13	
31.8	28.0	3.71	
35.3	15.0	4.17	
38.9	0.0		

TABLE D-54

21044/WABCO-DUAL	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121212	109.5 mph	
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	108.0	2.0	
0.5	107.0	2.63	
21.6	51.5	3.0	
27.1	35.0	3.50	
31.1	21.0	4.12	
36.2	0.0		

TABLE D-55

21044/WABCO-DUAL	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121401	81.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.5	1.50	
1.0	79.0	2.40	
15.1	45.2	2.68	
22.65	25.0	3.27	
30.3	0.0		

TABLE D-56

21044/WABCO-DUAL	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121403	60 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	59.5	1.60	
0.5	58.7	2.06	
5.7	48.0	2.52	
11.25	34.0	2.76	
18.85	13.0	3.21	
22.9	0.0		

TABLE D-57

21044/WABCO-DUAL	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121405	43.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	42.8	1.00	
0.8	42.0	2.29	
7.8	26.0	2.73	
13.3	11.0	3.06	
16.9	0.0		

TABLE D-58

21044/WABCO-DUAL	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121702	100.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	99.0	2.00	
20.3	58.5	2.31	
32.2	31.0	2.71	
39.2	12.0	3.43	
42.7	0.0		

TABLE D-59

21044/WABCO-DUAL	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121704	119 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	117.0	2.11	
33.2	47.0	2.51	
42.15	24.5	2.84	
45.6	14.7	3.42	
49.9	0.0		

TABLE D-60

21044/WABCO-DUAL	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121706	109 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	107.5	1.82	
0.55	106.5	2.23	
7.5	91.0	2.10	
28.0	48.0	2.61	
37.4	23.5	3.0	
41.4	11.5	3.48	
44.7	0.0		

TABLE D-61

21044/WABCO-DUAL	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121407	81 mph	-1
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.0	1.71	
0.7	78.8	2.77	
15.8	37.0	3.28	
22.35	15.5	4.25	
26.0	0.0		

TABLE D-62

21044/WABCO-DUAL	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121408	100 mph	+0.5
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	99.0	2.60	
7.3	80.0	2.52	
20.8	46.0	2.98	
26.85	28.0	3.39	
29.8	18.0	4.09	
34.2	0.0		

TABLE D-63

21044/WABCO-DUAL	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121409	61 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	60.0	2.00	
1.4	57.2	2.97	
9.45	33.3	3.36	
14.0	18.0	4.00	
18.5	0.0		

TABLE D-64

21044/WABCO-DUAL	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121410	108.5 mph	0 to +.3
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	107.5	2.55	
4.4	96.3	2.45	
21.9	53.5	2.87	
30.9	27.7	3.56	
35.4	11.7	4.18	
38.2	0.0		

TABLE D-65

21044/WABCO-DUAL	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121411	41.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	40.5	2.27	
1.85	36.3	3.12	
8.35	16.0	4.05	
12.3	0.0		

TABLE D-66

21044/WABCO-DUAL	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

121412	118 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	117.0	2.59	
7.35	98.0	2.45	
18.8	70.0	2.39	
27.3	49.7	2.83	
33.3	32.7	3.34	
38.3	16.0	4.27	
42.05	0.0		

TABLE D-67

21063/NYAB	HALF	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011001	79 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	78.5	1.24	
17.8	56.5	1.20	
45.2	23.5	1.56	
54.15	9.5	1.81	
59.4	0.0		

TABLE D-68

21063/NYAB	HALF	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011002	41 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	40.5	0.80	
1.25	39.5	1.20	
14.2	24.0	1.33	
23.2	12.0	1.62	
30.6	0.0		

TABLE D-69

21063/NYAB	HALF	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011003	117 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	116.5	1.37	
15.65	95.0	1.26	
41.05	63.0	1.26	
60.95	38.0	1.35	
72.4	22.5	1.50	
80.4	10.5	1.67	
86.7	0.0		

TABLE D-70

21063/NYAB	HALF	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011405	80 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	79.5	0.82	
39.5	47.0	1.10	
60.8	23.5	1,37	
67.9	13.8	1.57	
76.7	0.0		

TABLE D-71

21063/NYAB	HALF	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011406	41 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	40.8	0.95	
1.9	39.0	1.18	
14.6	24.0	1.30	
24.24	11.5	1.78	
30.7	0.0		

TABLE D-72

21063/NYAB	HALF	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011407	118 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	117.0	0.75	
0.67	116.5	1.46	
16.9	92.8	1.36	
62.0	31.5	1.55	
72.65	15.0	1186	
80.7	0.0		

TABLE D-73

21063/NYAB	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010701	81.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.5	1.43	
1.05	79.0	2.22	
19.3	38.5	2.38	
25.9	22.8	2.84	
30.4	10.0	3.33	
33.4	0.0		

TABLE D-74

21053/NYAB	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010703	100 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	98.5	1.37	
0.95	97.2	2.19	
11.1	75.0	2.09	
23.7	48.7	2.31	
33.3	26.5	2.61	
37.9	14.5	3.37	
42.2	0.0		

TABLE D-75

21063/NYAB	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010705	57 mph	+1
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	56.0	1.13	
1.5	54.3	2.24	
12.7	29.2	2.47	
18.85	14.0	3.29	
23.1	0.0		

TABLE D-76

21063/NYAB	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010803	41 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	40.0	1.29	
1.55	38.0	2.29	
8.1	23.0	2.72	
12.15	12.0	2.82	
16.4	0.0		

TABLE D-77

21063/NYAB	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010808	110 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	109.0	2.13	
8.0	92.0	1.94	
28.7	50.0	2.23	
41.35	24.0	2.44	
46.4	11.7	3.00	
50.3	0.0		

TABLE D-78

21063/NYAB	FULL	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010809	117 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	116.0	1.76	
0.85	114.5	2.15	
9.45	96.0	2.11	
33.7	44.8	2.46	
41.75	25.0	2.86	
45.25	15.0	3.30	
49.8	0.0		

TABLE D-79

21063/NYAB	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011008	78 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	77.0	1.82	
1.1	75.0	2.22	
16.5	40.8	2.38	
22.5	26.5	2.67	
28.0	11.8	3.37	
31.5	0.0		

TABLE D-80

21063/NYAB	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011010	55 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	54.0	1.14	
1.75	52.0	2.22	
13.25	26.5	2.70	
18.7	11.8	3.19	
22.4	0.0		

TABLE D-81

21063/NYAB	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011009	98.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	97.5	1.88	
0.8	96.0	2.13	
5.85	86.5	2.07	
26.7	42.0	2.32	
35.2	22.3	3.70	
39.2	11.5	3.38	
42.6	0.0		

TABLE D-82

21063/NYAB	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011011	107 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	105.5	1.58	
0.95	104.0	2.20	
6.4	92.0	1.98	
26.45	52.3	2.23	
38.9	24.5	2.67	
43.5	12.5	3.13	
47.4	0.0		

TABLE D-83

21063/NYAB	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011012	37.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	36.5	1.07	
1.4	35.0	2.11	
7.9	21.3	2.31	
11.4	13.2	3.00	
15.8	0.0		

TABLE D-84

21063/NYAB	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011013	116 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	115.0	0.53	
0.95	114.3	2.17	
14.4	85.3	1.91	
26.6	62.0	1.98	
32.4	50.5	2.31	
43.35	25.2	2.80	
52.35	0.0		

TABLE D-85

21063/NYAB	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010810	79 mph	-0.2
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	77.0	1.92	
1.3	74.5	3.15	
12.4	39.5	3.39	
18.3	19.5	--	B TRUCK 1.9 SEC
21.2	11.7	3.66	
24.4	0.0		

TABLE D-86

21063/NYAB	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010903	79.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	78.0	1.88	
0.8	76.5	2.90	
9.6	51.0	3.19	
17.6	25.5	3.46	
20.2	16.5	4.23	
24.1	0.0		

TABLE D-87

21063/NYAB	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010904	97 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	95.5	2.10	
1.05	93.3	3.00	
8.15	72.0	2.97	
24.3	24.0	3.68	
28.1	10.0		B TRUCK 1.5 SEC
31.1			

TABLE D-88

21063/NYAB	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010905	42.5	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	41.8	2.15	
1.3	39.0	3.17	
6.35	23.0	3.65	
9.5	11.5	--	B TRUCK 1.6 SEC
13.2			

TABLE D-89

21063/NYAB	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010906	116.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	115.0	2.50	
0.6	113.5	2.95	
6.7	95.5	2.69	
21.0	57.0	--	A TRUCK 0.9 SEC
23.5	51.5	2.54	
30.0	35.0	2.94	
35.1	20.0	3.27	
37.85	11.0	--	
38.35	9.0	--	B TRUCK 1.3 SEC
41.2			

TABLE D-90

21063/NYAB	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010907	60 mph	+0.5
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	59.0	2.40	
2.5	53.0	3.07	
7.55	37.5	3.58	
13.1	18.0	4.15	
15.15	9.5	--	B TRUCK 1.5 SEC
17.9			

TABLE D-91

21063/NYAB	EMERGENCY	50/50
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

010908	110 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	108.5	2.14	
0.7	107.0	2.91	
6.2	91.0	2.74	
19.9	53.5	2.94	
30.1	23.5	3.83	
33.1	12.0	--	B TRUCK 1.4 SEC
36.5			

TABLE D-92

21063/NYAB	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011107	79.5	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	78.0	1.88	
0.8	76.5	2.72	
5.4	64.0	2.78	
16.55	33.0	3.21	
22.15	15.0	3.70	
26.2	0.0		

TABLE D-93

21063/NYAB	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011108	97.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	96.0	2.25	
0.8	94.2	2.62	
7.55	76.5	2.54	
18.2	49.5	2.77	
27.4	24.0	3.64	
31.8	8.00	--	B TRUCK 1.4 SEC
34.86			

TABLE D-94

21063/NYAB	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO
011109	56 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	54.5	1.69	
1.3	52.3	3.11	
11.35	21.0	3.82	
14.75	8.00	--	B TRUCK 1.5 SEC
17.6	0.0		

TABLE D-95

21063/NYAB	EMERGECNY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011110	109 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	107.0	2.65	
8.3	85.0	2.59	
24.5	43.0	2.88	
31.1	24.0	3.62	
35.8	7.0	--	B TRUCK 0.9 SEC
37.7	0.0		

TABLE D-96

21063/NYAB	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011112	118 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	116.5	2.77	
6.5	98.5	2.61	
27.8	43.0	2.88	
34.4	24.0	3.44	
37.45	13.5	4.03	
40.8	0.0		

TABLE D-97

21063/NYAB	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

011111	38 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	37.2	2.31	
1.6	33.5	3.16	
5.56	31.0	3.54	
8.1	12.0	3.81	
11.25	0.0		

21087/KNORR	FULL	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

012202	99 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	98.5	1.30	
1.15	97.0	2.16	
19.75	56.8	2.40	
30.4	31.2	2.76	
35.9	16.0	3.27	
40.8	0.0		

TABLE D-99

21087/KNORR	FULL	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

012204	41.5	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	41.0	1.21	
1.65	39.0	2.09	
6.2	29.5	2.54	
13.1	12.0	3.00	
17.1	0.0		

TABLE D-100

21087/KNORR	FULL	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO
012206	80.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	79.5	1.25	
1.6	77.5	2.18	
8.7	62.0	2.48	
18.8	37.0	2.90	
26.9	13.5	3.46	
20.8	0.0		

TABLE D-101

21087/KNORR	FULL	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

012205	120.5 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	119.5	1.48	
1.35	117.5	2.32	
8.9	100.0	2.22	
29.6	54.0	2.48	
40.7	26.5	2.93	
45.3	13.0	3.42	
49.1	0.0		

TABLE D-102

21087/KNORR	FULL	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

012207	102.3 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	101.7	1.93	
1.4	99.0	2.16	
22.7	53.0	2.48	
30.75	33.0	2.76	
38.35	12.0	3.81	
41.5	0.0		

TABLE D-103

21087/KNORR	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013104	81.3 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.8	1.80	
1.0	79.0	2.13	
13.6	52.2	2.35	
23.7	28.5	2.49	
29.25	14.7	3.03	
34.1	0.0		

TABLE D-104

21087/KNORR	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013105	120 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	118.5	1.88	
0.8	117.0	2.26	
17.4	79.5	2.11	
29.5	54.0	2.24	
39.1	32.5	2.66	
45.6	15.2	2.98	
50.7	0.0		

TABLE D-105

21087/KNORR	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013106	44 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	43.3	1.13	
1.15	42.0	2.55	
8.7	25.3	2.63	
12.7	14.8	2.90	
17.8	0.0		

TABLE D-106

21087/KNORR	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013107	110.8 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	109.2	1.50	
0.8	108.0	2.21	
12.0	83.3	2.13	
30.65	43.5	2.51	
41.2	17.0	2.93	
47.0	0.0		

TABLE D-107

21087/KNORR	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013108	58.5 mph	-1
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	58.0	1.28	
2.5	54.8	2.39	
14.55	26.0	2.82	
18.1	16.0	2.96	
23.5	0.0		

TABLE D-108

21087/KNORR	FULL	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013109	102.5	-0.5
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	100.5	1.37	
0.95	99.2	2.19	
22.65	51.7	2.29	
31.7	31.0	2.54	
38.8	13.0	3.17	
42.9	0.0		

TABLE D-109

21087/KNORR	EMERGENCY	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013003	81 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	80.5	1.85	
1.35	78.0	3.02	
9.95	52.0	3.29	
17.55	27.0	3.91	
21.0	13.5	--	A TRUCK 1.1 SEC
23.8	5.0	--	A TRUCK 0.05 SEC
24.5	0.0		

TABLE D-110

21087/KNORR	EMERGENCY	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013004	101.8 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	100.5	1.79	
1.4	98.0	2.95	
7.5	80.0	2.92	
18.1	49.0	3.36	
24.65	27.0	3.68	
29.0	11.0	--	A TRUCK 1.0 SEC
32.1	0.0		

TABLE D-111

21087/KNORR	EMERGENCY	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013005	111 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	110.1	1.58	
0.95	108.5	2.74	
10.1	83.7	2.66	
22.6	50.5	3.09	
30.5	27.0	3.57	
33.0	17.0	--	A TRUCK 1.2 SEC
36.3	7.5	--	A TRUCK 0.7 SEC
38.2	0.0		

TABLE D-112

21087/KNORR	EMERGENCY	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013101	39 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	38.8	1.29	
1.4	37.0	3.07	
8.9	14.0	3.68	
12.7	0.0		

TABLE D-113

21087/KNORR	EMERGENCY	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013102	120 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	119.0	1.79	
1.4	116.5	2.85	
7.9	98.0	2.57	
27.55	47.5	2.87	
34.6	27.3	3.33	
38.6	14.0	3.65	
41.2	45.0	--	
42.5	0.0		

TABLE D-114

21087/KNORR	EMERGENCY	70/30
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013103	58.8 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	59.5	1.58	
1.9	56.5	3.26	
8.5	35.0	3.50	
14.5	14.0	3.85	
17.1	4.0	-	A TRUCK 0.2 SEC
18.05	0.0		

TABLE D-115

21087/KNORR	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013110	82.0 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	81.3	0.80	
1.0	80.5	2.61	
11.65	52.7	2.88	
19.7	29.5	3.33	
23.75	16.0	3.56	A TRUCK 4 MPH .15 SEC
28.25	0.0		A TRUCK 3 MPH 0.01 SEC

TABLE D-116

21087/KNORR	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013111	101 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	100.0	1.20	
1.0	98.8	2.57	
60.5	85.5	2.52	
26.2	35.0	3.23	
32.7	14.0	3.89	
36.3	0.0		

TABLE D-117

21087/KNORR — CAR NO/BRAKE TYPE

EMERGENCY — BRAKE SERVICE

60/40 — DISC/TREAD RATIO

013112 — RUN NO.

58.5 mph — SPEED

-0.5 — SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	57.8	1.35	
1.7	55.5	2.97	
11.3	27.0	3.57	
14.8	14.5	3.80	
17.3	5.00	--	A TRUCK 0.1 SEC
17.5	4.5	--	A TRUCK 0.4 SEC
18.6	0.0		

TABLE D-118

21087/KNORR	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013113	120 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	118.7	1.71	
0.7	117.5	2.62	
6.8	101.5	2.50	
19.4	70.0	2.15	
23.45	61.3	2.65	
31.5	40.0	2.97	
40.6	13.0	4.00	
43.85	0.0		

TABLE D-119

21087/KNORR	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013114	44.8 mph	
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	43.8	1.25	
1.28	42.2	3.00	
7.25	24.3	3.35	
14.5	0.0		

TABLE D-120

21087/KNORR	EMERGENCY	60/40
CAR NO/BRAKE TYPE	BRAKE SERVICE	DISC/TREAD RATIO

013115	109 mph	0
RUN NO.	SPEED	SPEED BIAS

T (SECONDS)	V (MPH)	dV/dT MPH/SEC.	COMMENTS
0.0	108.0	1.88	
0.8	106.5	2.70	
8.4	86.0	2.46	
22.5	51.3	2.69	
31.55	27.0	3.33	
35.6	13.5	4.09	
37.8	4.5	--	A TRUCK 0.2 SEC
38.1	4.0	--	A TRUCK 0.15 SEC
38.35	3.0	--	A TRUCK 0.02 SEC
39.0	0.0		

APPENDIX E

REDUCED PRESSURE BRAKING TEST

ENSCO PUB. NO. DOT-FR-80-16

TESTS RESULTS REPORT

DUAL BRAKE EVALUATION PROGRAM
REDUCED-PRESSURE BRAKING TEST

Contract DOT-FR-64113
Task 477

NOTE

This special report covers one phase of the Dual Brake Evaluation Program conducted in cooperation with Amtrak under their Contract WHS 9282-035. Material included in this report will be included in the final report on the Dual Brake Evaluation Program to be prepared under FRA Contract DOT-FR-64113 (Task 477).

Prepared for:

DEPARTMENT OF TRANSPORTATION
Federal Railroad Administration
Office of Passenger Systems
400 Seventh Street, S.W.
Washington, DC 20590

March 1980

Prepared by:

RAIL TRANSPORTATION ENGINEERING DIVISION
ENSCO, INC.
2560 Huntington Avenue
Alexandria, VA 22303

EXECUTIVE SUMMARY

As part of the Dual Brake Evaluation Test, a special test was run on a standard Amcoach car (equipped with only disc brakes) to demonstrate stopping performance at a reduced braking rate. The test showed that the reduced braking rate could be achieved by readjusting the 26-C control valve on the car, and that reducing the full-service braking pressure from the current 68 psi to 55 psi increased the single-car-stopping-distance by only 700 feet (from 4900 to 5600 feet) for stops from 120 miles per hour.

This reduction in braking rate could make a significant improvement in the wheel damage experienced by Amcoach cars particularly in wet weather, or when oil films or other contamination cause poor adhesion. With normal full-service brake pressure, the adhesion demand increased sharply as the car slowed to below 30 mph. At very slow speeds the adhesion demand with normal brake pressure was significantly above the predictable levels of adhesion for wet rail conditions and nearly equal to the upper limits of adhesion for dry rail. During one 80-mph, normal-full-service-braking rate test, a wheel slide occurred at about four mph under ideal dry rail conditions.

The results from tests made with reduced brake cylinder pressure show that in addition to reducing the overall braking rate, the major change was a reduction in the stopping rate at speeds below 30 mph. The braking rate and therefore the adhesion demand appeared to reach a limit of 0.12 g's (implying that the adhesion demand was also approximately 0.12) below 15 mph. With the reduced-pressure, full-service stop, the adhesion demand was more consistent with the available adhesion for weather and rail conditions characteristic of the Northeast Corridor.

Adding tread brakes to supplement the existing disc brake system on the Amcoach cars (operating in NEC service or in other regions which have poor adhesion) may be the best technical solution to reducing wheel damage. However, the results of this test demonstrate that readjusting the rate limiting section of the 26-C control valve thereby reducing full service brake cylinder pressure, may provide an alternate solution which would be far less expensive. Tread brakes or disc brakes combined with tread brakes or wheel scrubbers are better than disc brakes alone under wet rail or poor adhesion conditions because the scrubber or tread brake improves the available adhesion. The tread brake or scrubber keeps the wheel surface clean and may seed the wheel surface with material which aids adhesion.

The results of this test show that reducing the braking rate by limiting the brake cylinder pressure may provide a significant reduction in the wheel damage experienced by Amcoach cars without significantly increasing stopping distance.

1.0 INTRODUCTION

As part of the Dual Brake Evaluation Test performed by ENSCO at the Transportation Test Center (TTC) for the Federal Railroad Administration (FRA) and Amtrak, a special test was performed to demonstrate the feasibility of operating standard Amcoaches at reduced braking rates. Analysis of the results of the braking requirements study performed earlier by ENSCO under the Passenger Vehicle Braking Study, Report FRA/ORD-78/33) strongly suggested that the Amcoaches might be over-braked as far as actual operational requirements are concerned.

The present plan for the NEC signaling system may increase the signal blocks to 12,000 or 13,000 feet. With full-service brake application, a single Amcoach stops in under 6,000 feet from 120 mph. This might be considered very good, but a review of the records of Amcoach wheel life showed that the price for achieving this stopping distance is paid for in wheel damage.

The feasibility of reducing the braking rate on Amcoaches was reviewed with Amtrak, and a plan for performing a demonstration test was added to the Dual Brake Evaluation Test. This test was performed by ENSCO during the brake test at TTC. The results of testing the standard Amcoach with normal (68 psi) brake cylinder pressure for full-service brake application and on the same car with the system readjusted to develop 55 psi for full-service brake application are listed in this report. The reduction in brake-cylinder pressure was accomplished by readjusting the 26-C valve. Amtrak selected this pressure so that at the lower pressure, the Amcoach braking rate would be compatible with that of the older passenger cars in the Amtrak fleet.

In part, this test was made to demonstrate that the existing brake valve can be readjusted to obtain the desired brake application pressure.

2.0 TEST DETAILS

Using the special release coupler set up for the Dual Brake Evaluation test, the Amcoach was towed up to speeds ranging from 40 to 124 mph and then cut away as a single car. After the car was free from the locomotive, a full-service brake application was made using a special conductor valve located in the test coach. By releasing air, the brake-pipe pressure was reduced causing a normal full service brake application. A series of test runs were made at normal full-service braking (68 psi brake cylinder pressure) and the tests were repeated at the reduced pressure after the 26-C valve was adjusted to apply only 55 psi pressure to the brake cylinders.

3.0 TEST RESULTS

The speed and stopping distances were measured and the results from both series of tests are shown in Figure 3-1 and the tabulated data is shown in Tables 3-1 and 3-2. In Table 3-1 the data are listed in run number order and in Table 3-2 in decreasing order of speed. At the reduced rate, the car stopped from 120 mph in about 5,600 feet compared to 4,900 feet for the normal full service stop. The total time (not including time for the pressure build up) was 59.5 seconds with reduced pressure and 52.5 seconds with normal full-service pressure. If the system has a constant coefficient of friction, the energy at any time is described by:

Kinetic Energy = Initial Kinetic Energy - Work Done

$$KE = KE\ (\text{initial}) - F \times D$$

$$1/2\ MV_2^2 = 1/2\ MV_{\text{initial}}^2 - FD$$

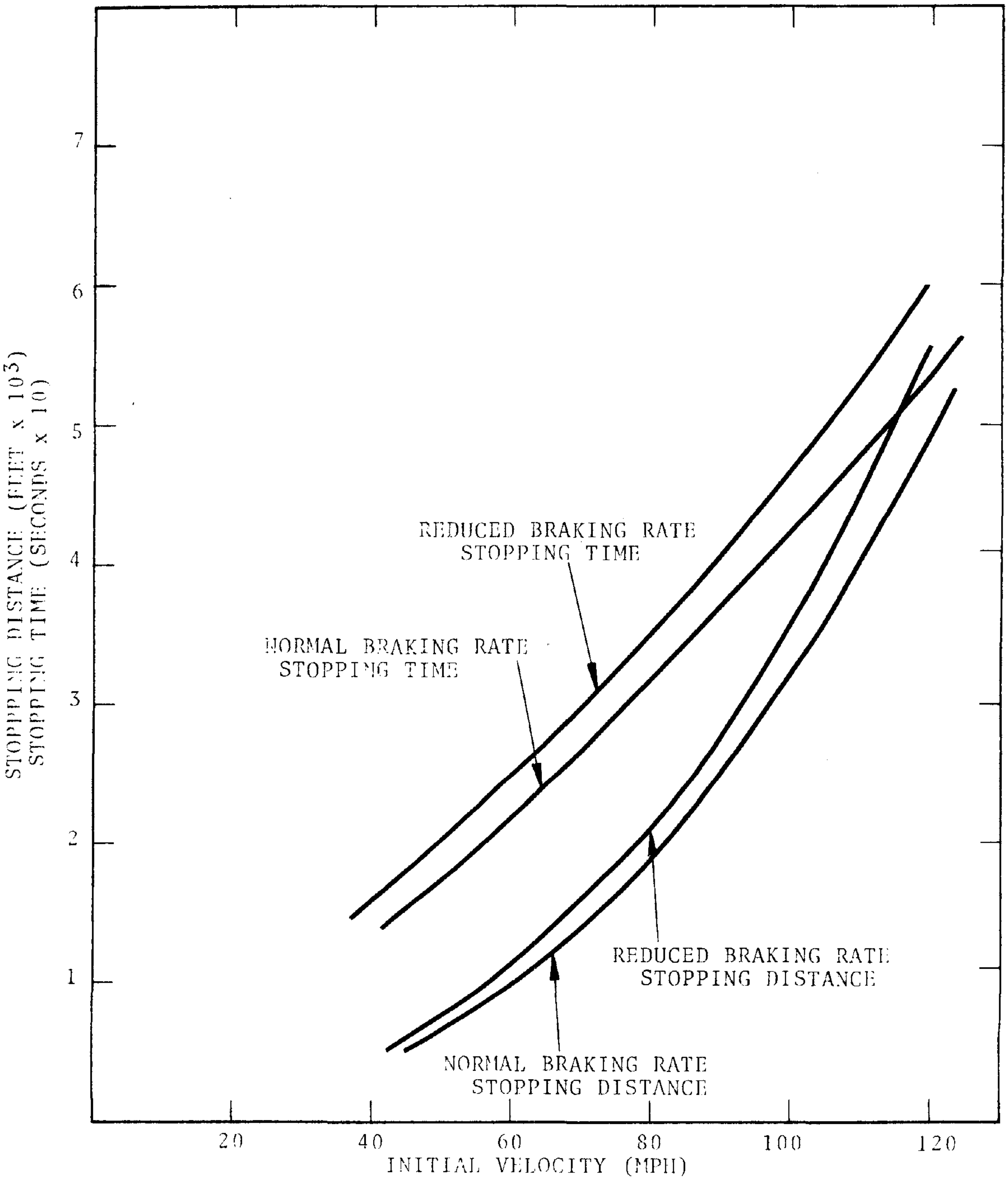

Figure 3-1. Stopping Distance and Time vs. Initial Velocity

TABLE 3-1

TEST RESULTS - STANDARD AMCOACH
NOMINAL AND REDUCED FULL-SERVICE BRAKING RATE
(Run Number Order)

Run No.	Speed (V_i) (mph)	Stop Distance (D) (Feet)	Apparent Coefficient of Friction (μ)	Stop Time (t) (Seconds)
Brake Cylinder Pressure -- Normal Full Service Braking (68 psi)				
112801	82.0	2,207	.10	33.9
112802	103.0	3,664	.096	45.2
112803	63.0	1,222	.107	23.9
112804	113.0	4,380	.096	50.1
112805	45.0	545	.1226	15.5
112806	124.0	5,313	.096	54.9
112903	83.0	2,186	.104	33.2
112904	100.0	3,203	.103	40.6
112905	44.0	531	.120	15.7
112906	117.0	4,559	.099	50.0
112907	64.0	1,133	.119	22.5
112908	107.0	3,834	.098	45.4
112909	43.0	547	.112	15.7
112910	115.0	4,439	.098	49.9
113001	84.0	2,112	.110	32.8
113002	101.0	3,340	.100	41.8
113003	64.0	1,138	.119	23.2
113004	109.0	4,088	.096	48.1
Brake Cylinder Pressure -- Reduced Braking (55 psi)				
020501	110.0	4,484	.089	53.1
020502	81.5	2,174	.100	34.6
020503	101.0	3,602	.090	46.0
020504	41.5	571	.0995	17.4
020506	119.5	5,512	.085	59.5
020507	41.0	545	.10	17.0
020508	110.0	4,634	.086	54.0
020509	82.0	2,312	.096	35.4
020510	99.0	3,596	.090	46.2
020511	119.0	5,501	.085	59.6

TABLE 3-2

TEST RESULTS - STANDARD AMCOACH
NOMINAL AND REDUCED FULL-SERVICE BRAKING RATE
(In Order of Speed)

Speed (V_i) (mph)	Stopping Distance (D) (Feet)	Apparent Coefficient of Friction (μ)	Stopping Time (t) (Seconds)
Brake Cylinder Pressure -- Normal Full Service (68 psi)			
124	5313	.096	54.9
117	4559	.099	50.0
115	4439	.098	49.9
113	4380	.096	50.1
109	4088	.096	48.1
107	3834	.098	45.4
103	3664	.096	45.2
101	3340	.100	41.8
100	3203	.103	40.6
84	2112	.110	32.8
83	2186	.104	33.2
82	2207	.100	33.9
64	1133	.120	22.5
64	1138	.119	23.2
63	1222	.107	23.9
45	545	.123	15.5
44	531	.120	15.7
43	547	.112	15.7
Brake Cylinder Pressure -- Reduced Pressure (55 psi)			
119.5	5512	.085	59.6
119	5501	.085	59.6
110	4484	.089	53.1
110	4634	.086	54.0
101	3602	.090	46.0
99	3596	.090	46.2
82	2312	.096	35.4
81.5	2174	.100	34.6
41.5	571	.0995	17.4
41	545	.100	17.0

where

D = stopping distance in feet
V_1 and V_2 = velocity in feet/second
$F = W_1 \mu$
$W = Mg$
$F = Mg\mu$

Discounting the wind and the rolling resistance

$$1/2\ MV_2^2 = 1/2\ MV_1^2 = Mg\mu D$$

after the car has stopped $V_2 = 0$

$$Mg\mu D = 1/2\ MV_1^2$$

$$2g\mu D = V_1^2$$

$$\mu = V_1^2/2gD = V_1^2/64.4D$$

if V_1 is in mph, the average rolling friction during the stop (μ) is:

$$\mu = 0.033(V_1)^2/D$$

With normal pressure (68 psi) at 120 mph, D = 4,900

$$\mu_{AV_{120}} = \frac{0.033\ (120)^2}{4900} = 0.097 \text{ normal full service braking}$$

$$\mu_{AV_{120}} = \frac{0.033\ (120)^2}{5600} = 0.085 \text{ reduced full service braking}$$

A similar comparison for stops made from 80 mph

$$\mu_{AV_{80}} = \frac{0.033\ (80)^2}{1950} = 0.108 \text{ normal full service braking}$$

$$\mu_{AV_{80}} = \frac{0.033\ (80)^2}{2175} = 0.097 \text{ reduced full service braking}$$

In a similar manner, the average apparent coefficients including wind and rolling resistance) have been computed and the adhesion vs. initial velocity are plotted in Figure 3-2.

The results shown in Figure 3-2 clearly indicate that the average adhesion demand was reduced by reducing brake pressure.

The test results shown in Figure 3-1 were analyzed and a power equation of the form:

$$Y = aX^b$$

was fit to the test data for each series of tests.

The equation describing normal full service is:

$$D = 0.12V^{2.22}$$

and the equation for reduced pressure is:

$$D = 0.19V^{2.15}$$

Both the normal service and the reduced pressure braking data agreed reasonably well with the general formula since in both cases the exponent of V is nearly 2 as predicted.

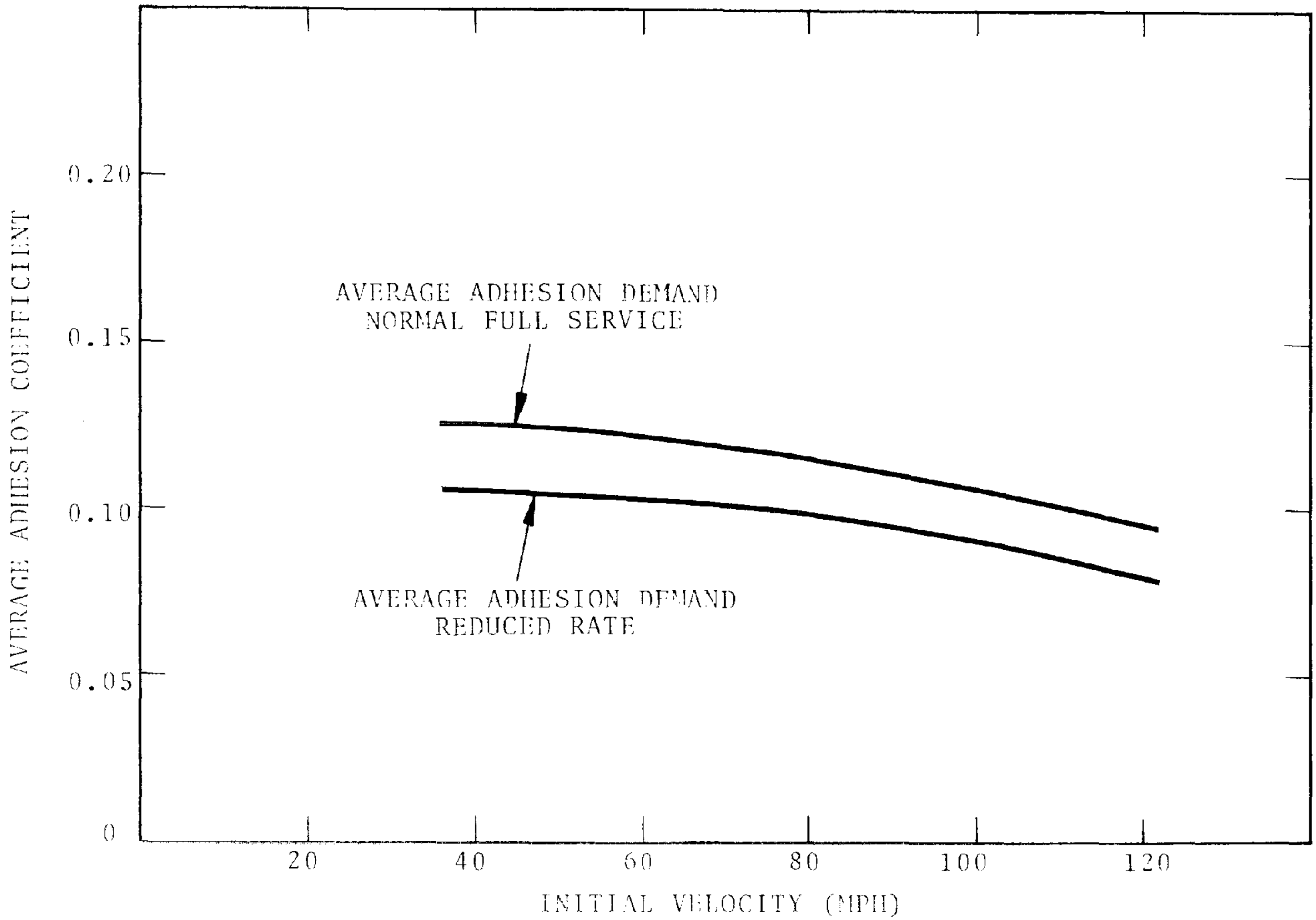

Figure 3-2. Adhesion Demand vs. Initial Velocity

In addition, several of the runs were analyzed to determine the instantaneous deceleration rate. For this analysis, the change in velocity was determined for two-second periods. Since,

$$\text{Average acceleration} = \frac{\Delta V}{\Delta t}$$

$$\text{Acceleration} = \lim_{t \to 0} \frac{\Delta V}{\Delta t}$$

The acceleration was computed for the standard Amcoach, normal-pressure runs at 120 mph and 80 mph and equivalent runs from the reduced-pressure test series. The deceleration data is tabulated in Table 3-3 (at present the data are from only one of the series). The deceleration data from these individual runs are shown in Figure 3-3. When the pressure was reduced, the major change occured at low speeds. With normal pressure, the deceleration increases sharply at speeds below 30 mph. With reduced pressure adjustment, the deceleration reached a limit of 0.12 g's.

Figure 3-3 shows deceleration vs. speed, but this data can be related to instantaneous adhesion demand from the free body diagram shown in Figure 3-4.

TABLE 3-3

PRELIMINARY DATA

Brake Cylinder Pressure - 68 psi

Run 112801 (80 mph)
dV/dt = 2.43 (overall)

Time	Speed	ds/dt mphps	ds/dt g's
0	80.5	1.60	0.073
5	70.5	2.10	0.096
10	60.0	2.10	0.096
15	50.0	2.15	0.098
20	39.0	2.55	0.116
25	26.0	2.70	0.123
30	11.5	3.60	0.164
31.5*	4.0	4.15	0.189

*Just prior to wheel slip.

Run 112806 (120 mph)
dV/dt = 2.26 (overall)

Time	Speed	ds/dt mphps	ds/dt g's
0	122.0	1.60	0.073
5	112.0	2.05	0.093
10	101.5	2.10	0.096
15	91.0	2.00	0.091
20	81.5	2.00	0.090
25	71.0	1.95	0.089
30	61.0	2.00	0.091
35	51.0	2.10	0.096
40	40.0	2.15	0.098
45	29.0	2.50	0.114
50	15.0	3.15	0.143
54	2.0	3.45	0.157

Brake Cylinder Pressure - 55 psi

Run 020509 (80 mph)
dV/dt = 2.32 (overall)

Time	Speed	ds/dt mphps	ds/dt g's
0	81.0	1.55	0.070
5	72.0	1.90	0.086
10	62.0	1.95	0.089
15	52.5	2.10	0.096
20	41.0	2.30	0.105
25	29.5	2.50	0.114
30	16.5	2.60	0.118
35	2.0	2.60	0.118

Run 020506 (120 mph)
dV/dt = 2.01 (overall)

Time	Speed	ds/dt mphps	ds/dt g's
0	118.5	1.50	0.068
5	108.5	1.90	0.086
10	99.0	1.85	0.084
15	90.0	1.80	0.082
20	81.0	1.80	0.082
25	72.0	1.70	0.077
30	64.0	1.70	0.077
35	55.0	2.00	0.091
40	45.0	2.00	0.091
45	35.0	2.15	0.098
50	24.0	2.50	0.114
55	11.0	2.60	0.118
59	1.5	2.60	0.118

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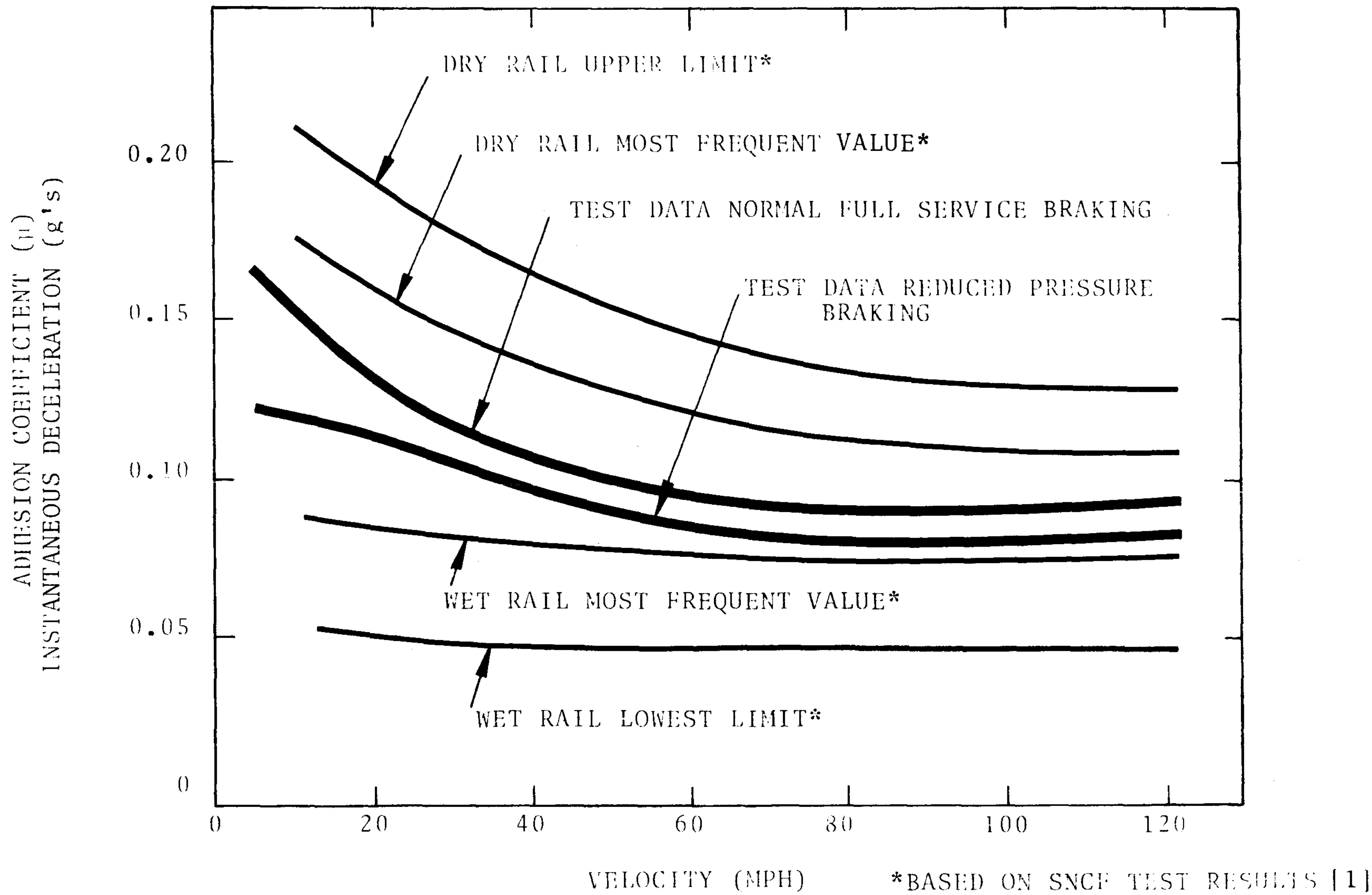


Figure 3-3. Deceleration and Adhesion vs Velocity

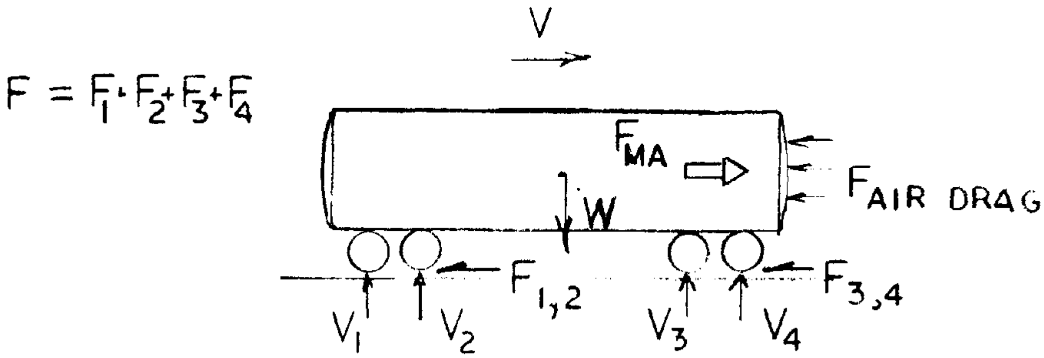


Figure 3-4. Free Body Diagram of Railcar

$F_{MA} = F_{Friction} + F_{(Wind\ +\ Rolling)}$

$F_{MA} = F_{Friction}$ (omitting wind and rolling resistance)

F_{MA} = Normal Force x Coefficient of Friction

$N = W = mg$

$F_{MA} = MA$

$MA = Mg\mu$

$A = g(\mu)$

If A is expressed in g's

$A = ag$

$a(g) = g(\mu)$

$a = \mu$

The available adhesion data from the French National Railroad (SNCF) reports [1] is overlaid on the uncorrected adhesion demand data for disc brakes in Figure 3-3.

4.0 CONCLUSIONS

The results of the reduced-braking-rate test show that the braking rate and therefore the adhesion demand is reduced when the brake cylinder pressure for full-service application is 55 psi instead of the normal 68 psi.

The test shows that the reduction can be accomplished by readjusting the 26-C control valve which is part of the existing brake system on the Amcoach cars.

When the results from the test are compared with SNCF data on available adhesion, the comparison seems to indicate that the reduction in braking rate (accomplished by reducing the brake cylinder pressure) may make a significant improvement in the tendency to cause wheel slide and, therefore, could cause a significant decrease in the amount of wheel damage experienced by Amcoach cars.

The reduction appears to be most significant at lower speeds and probably will make the most difference in regions where the adhesion is less than ideal. If the cars were equipped with tread brakes or wheel scrubbers, the higher adhesion levels demanded for normal full-service braking would probably be more acceptable.

Tread brakes or scrubbers tend to clean the wheel surface and seed the surface with material which improves the wheel-to-rail adhesion. There is also some evidence which shows that tread brakes also help to minimize the damage resulting from momentary wheel sliding. When the adhesion demand exceeds the available adhesion, the wheel will start to slide. The slide control system (if it is working properly) detects the acceleration or velocity differences and releases the pressure from the brake cylinder to prevent further sliding, but by the time the system releases the pressure from the brake cylinder, some damage has already occured. Tread brakes tend to reduce the amount of damage by preventing sliding and by reducing the severity of the damage when wheel sliding occurs.

Equipping cars with both tread and disc brakes is probably the best technical solution but the test shows that reducing the cylinder pressure may significantly reduce wheel damage particularly in NEC operation where adhesion is less than ideal becasue of wet rail conditions and industrial contamination.

Reducing the brake cylinder pressure does nothing to improve the available adhesion but the reduction in demand may be enough to reduce the tendency to slide. This would place less demand on the slide control system and might reduce wheel damage while increasing the stopping distance only from 4900 feet to 5600 feet for a full-service stop from 120 mph.

Increasing the stopping distance by 700 feet is probably an acceptable price to pay for a potential reduction in wheel damage.

REFERENCES

[1] Laplaiche, M., Freinage des Trains a Grandes Vitesses. Colleque ORE Grandes Vitesses, 1971.

APPENDIX F

ADHESION DATA

The following figures show typical wheel to rail adhesion data. The data shown in Figure F-1 have been extracted from tests conducted by SNCF (French National Railways). The material appears in a paper titled, "Freinage des Trains a Grandes Vitesses".

Similar data shown in Figure F-2 have been provided to FRA by representatives of the Japanese National Railroad (JNR). The JNR data are based both on historical experience and tests on series 155 trailer coaches, and tests of series 591 EMU cars conducted in 1970 and a similar series conducted in 1971. The tests on the 155 series coaches were performed in 1965.

The 1975 Amcoach equipment specification sites similar adhesion data for wet and dry rail conditions. The Amtrak data are shown in Figure F-3. Figure F-4 shows data from the above sources combined on a single graph.

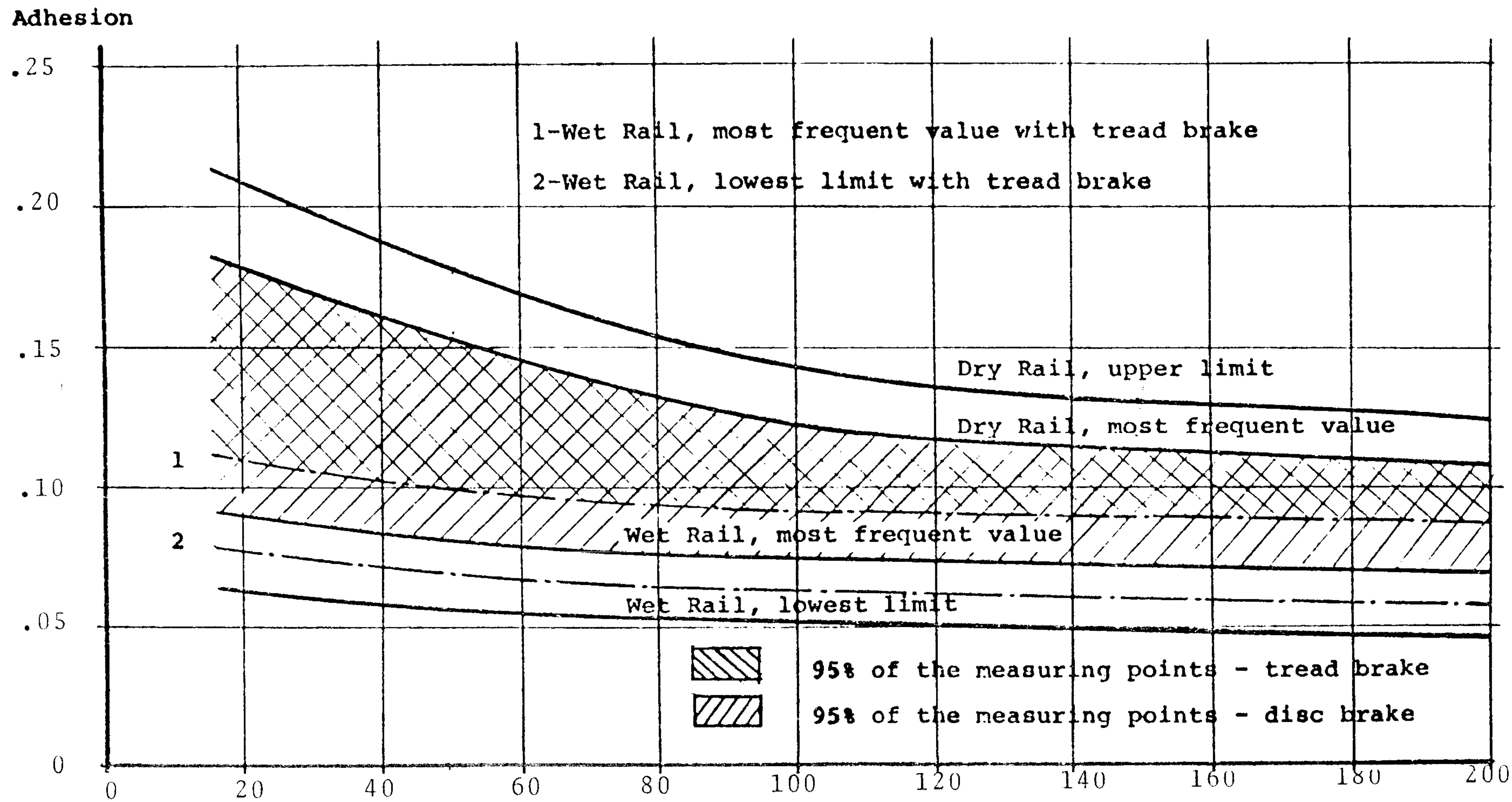
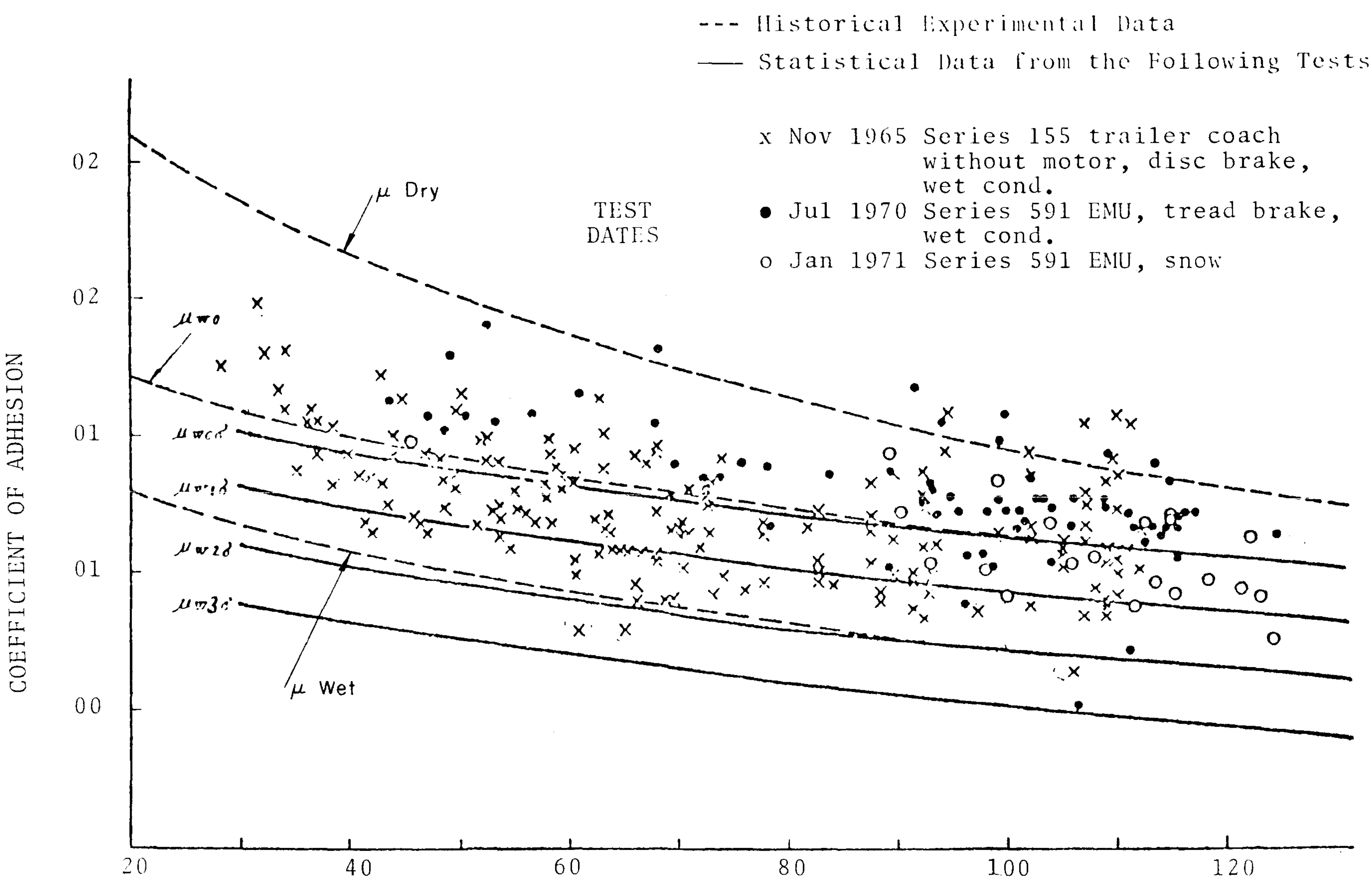


Figure F-1. Adhesion vs. Speed from Tests Run By SNCF (French National Railways)



DATA PROVIDED FRA

Figure F-2. Adhesion vs Speed Data from the Japanese National Railroad

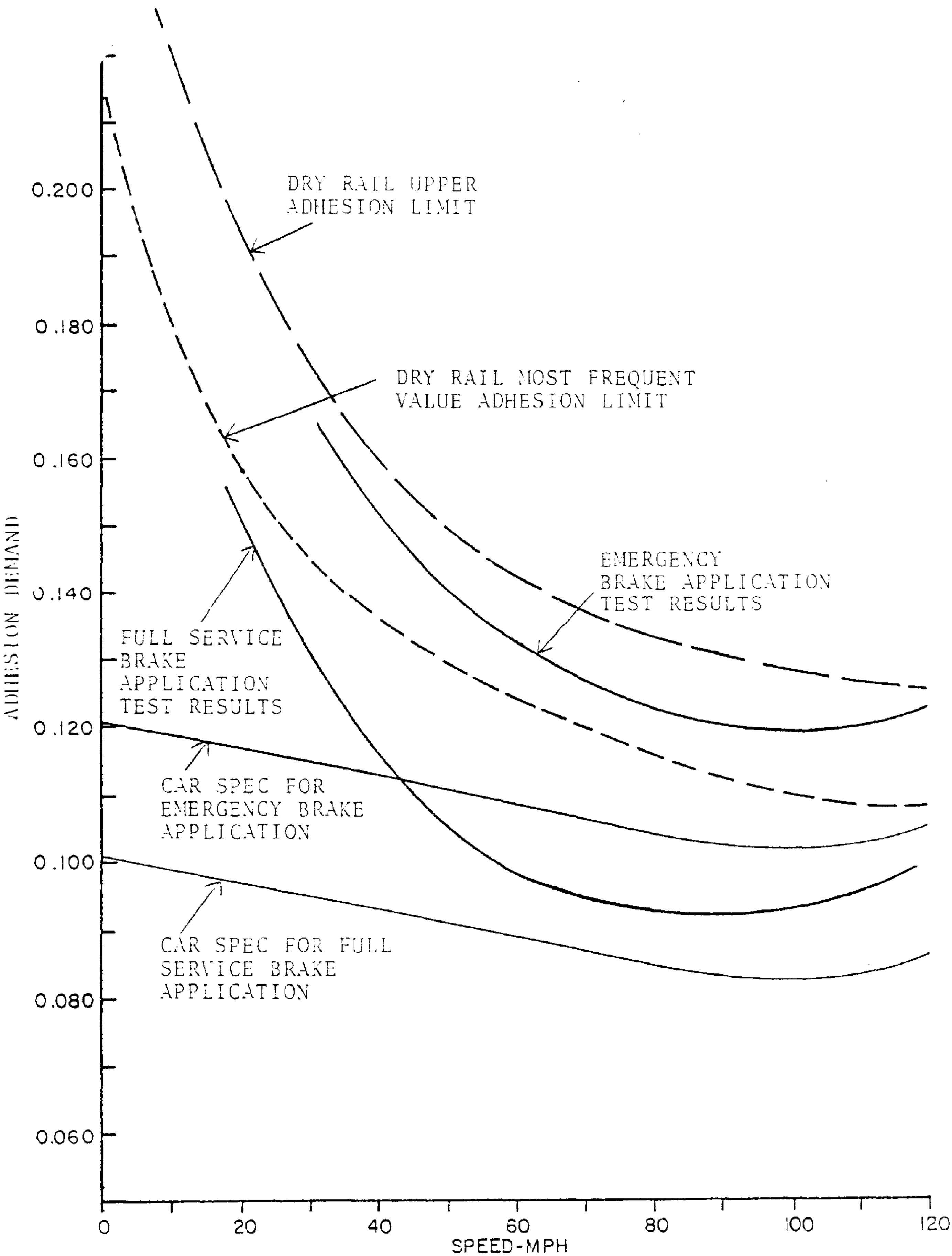


Figure F-3. Adhesion vs Speed Data from Amtrak

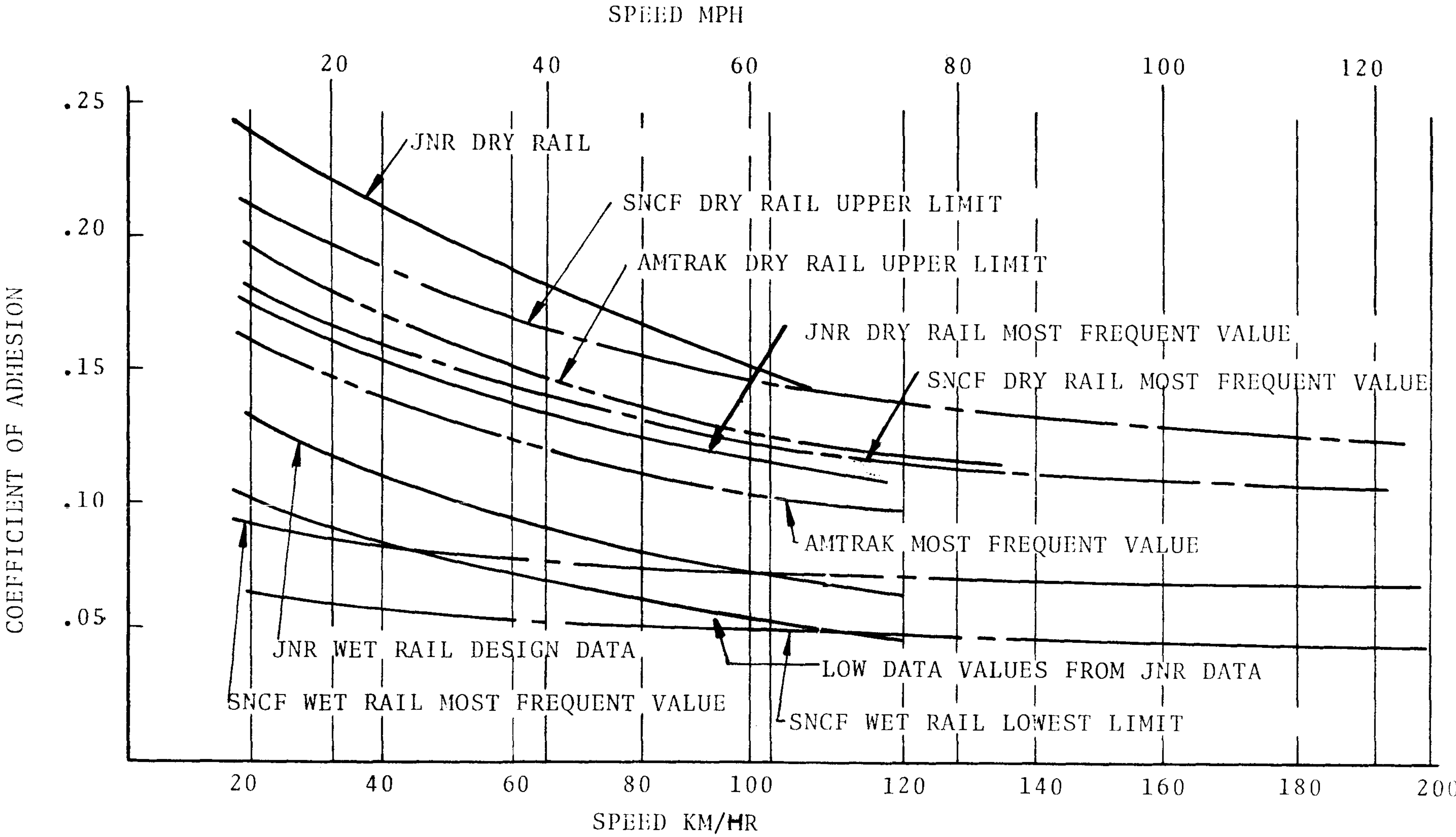


Figure F-4. Graph of Adhesion vs Speed Data from SNCF, JNR and Amtrak.